CHAPTER

1

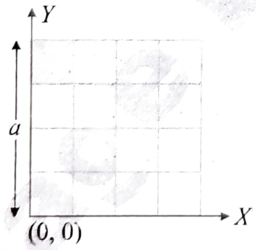
Center of Mass

DPP 1.1

Center of Mass

Subjective Type

1. From a uniform square plate the shaded portions are removed as shown in the figure. Find the coordinates of centre of mass of the remaining plate. X- and Y-axes and origin are shown in the figure.

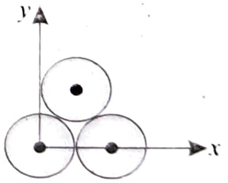


Single Correct Answer Type

2. Mass is non-uniformly distributed on the circumference of a ring of radius a and centre at origin. Let be the distance of centre of mass of the ring from origin. Then
(a) $b = a$ (b) $0 \le b \le a$
(c) $b < a$ (d) $b > a$

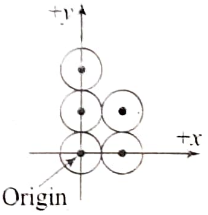
3. The centre of mass of a system of particles is at (x_0, y_0, z_0) where $x_0 \le 0$, $y_0 \le 0$. It is known that no particle lies in the region $y < 0$ and $x < 0$, then the position of centre of mass can be
(a) $(0, 0, 4)$ (b) $(0, -4, 0)$
(c) $(-4, 0, 0)$ (d) $(-4, -4, 4)$

4. Three identical spheres each of radius R are placed touching each other on a horizontal table as shown in the figure. The coordinates of center of mass are:

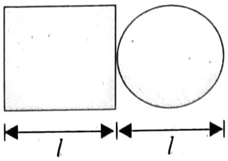


(a) (R, R) (b) $(0, 0)$ (c) $\left(\frac{R}{2}, \frac{R}{2}\right)$ (d) $\left(R, \frac{R}{\sqrt{3}}\right)$

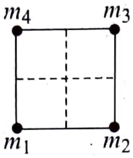
5. Five uniform circular plates, each of diameter b and mass m, are laid out in a pattern shown. Using the origin shown, find the y coordinate of the center of mass of the five-plate system.



(a) $b/5$ (b) $b/3$
(c) $4b/5$ (d) $2b/5$



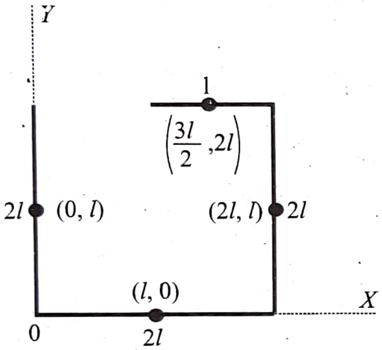
6. If the density of the material of a square plate and a circular plate shown in the figure is the same, the center of mass of the composite system will be
- (a) inside the square plate
- (b) inside the circular plate
- (c) at the point of contact
- (d) outside the system



7. Four particles of mass $m_1 = 2m$, $m_2 = 4m$, $m_3 = m$ and m_4 are placed at four corners of a square. What should be the value of m_4 so that the centre of mass of all the four particles is exactly at the centre of the square?

(a) 2 m (b) 8 m (c) 6 m (d) none of these

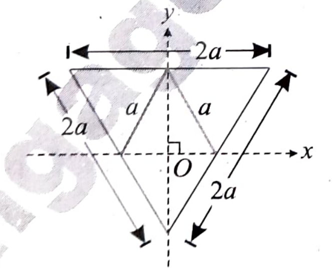
8. A wire of uniform cross-section is bent in the shape shown in the figure. The coordinates of the center of mass of each side are shown in the figure. The coordinates of the center of mass of the system are



(a) $\left(\frac{15l}{14}, \frac{6l}{7}\right)$ (b) $\left(\frac{15l}{14}, l\right)$

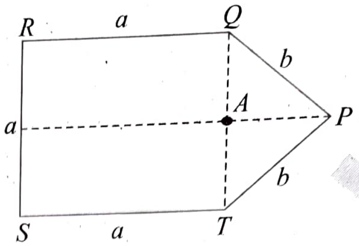
(c) $\left(l, \frac{l}{2}\right)$ (d) (l, l)

9. The 'y' coordinate of the centre of mass of the system of three rods of length '2a' and two rods of length 'a' as shown in the figure is: (Assume all rods to be of uniform density)



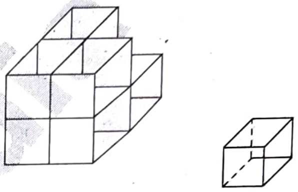
(a) $\frac{9a}{8\sqrt{3}}$ (b) $\frac{9a}{16\sqrt{3}}$ (c) zero (d) $\frac{8a}{\sqrt{3}}$

10. A homogeneous plate $PQRST$ is as shown in the figure. The centre of mass of plate lies at midpoint A of segment QT. Then the ratio of $\frac{b}{a}$ is ($PQ = PT = b$; $QR = RS = ST = a$)



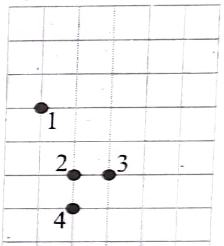
(a) $\frac{13}{4}$ (b) $\frac{13}{2}$ (c) $\sqrt{\frac{13}{2}}$ (d) $\sqrt{\frac{13}{4}}$

11. Eight solid uniform cubes of edge l are stacked together to form a single cube with center O. One cube is removed from this system. Distance of the centre of mass of remaining 7 cubes from O is



(a) $\frac{7\sqrt{3}l}{16}$ (b) $\frac{\sqrt{3}l}{16}$ (c) $\frac{\sqrt{3}l}{14}$ (d) zero

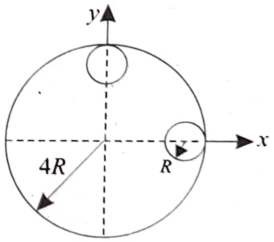
12. In the figure, the L-shaped shaded piece is cut from a metal plate of uniform thickness. The point that corresponds to the center of mass of the L-shaped piece is:



(a) 1 (b) 2

(c) 3 (d) 4

13. From the circular disc of radius $4R$ two small discs of radius R are cut off. The centre of mass of the new structure will be:



(a) $i\frac{R}{5} + j\frac{R}{5}$ (b) $-i\frac{R}{5} + j\frac{R}{5}$

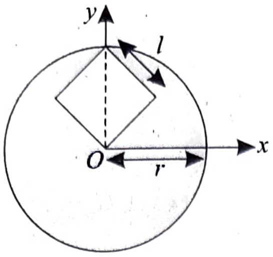
(c) $\frac{-3R}{14}(\hat{i} + \hat{j})$ (d) None of these

14. From the circular disc of radius $4R$ two small discs of radius R are cut off. The centre of mass of the new structure will be: (Centre of lower circular cavity lies on x-axis and centre of upper circular cavity lies on y-axis)

(a) $\hat{i}\frac{R}{5} + \hat{j}\frac{R}{5}$ (b) $-\hat{i}\frac{R}{5} + \hat{j}\frac{R}{5}$

(c) $-\hat{i}\frac{R}{5} - \hat{j}\frac{R}{5}$ (d) $-\frac{3R}{14}(\hat{i} + \hat{j})$

15. A disc (of radius r cm) of uniform thickness and uniform density ρ has a square hole with sides of length $l = \frac{r}{\sqrt{2}}$ cm. One corner of the hole is located at the center of the disc and centre of the hole lies on y-axis as shown. Then the y-coordinate of position of center of mass of disc with hole (in cm) is



(a) $-\frac{r}{2(\pi - 1/4)}$ (b) $-\frac{r}{4(\pi - 1/4)}$

(c) $-\frac{r}{4(\pi - 1/2)}$ (d) $-\frac{3r}{4(\pi - 1/4)}$

Answers Key

Subjective Type

1. $\left(\frac{55a}{104}, \frac{49a}{104}\right)$

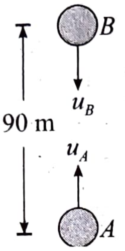
Single Correct Answer Type

2. (b)	**3.** (a)	**4.** (d)	**5.** (c)	**6.** (a)
7. (d)	**8.** (a)	**9.** (b)	**10.** (d)	**11.** (c)
12. (b)	**13.** (c)	**14.** (d)	**15.** (c)	

DPP 1.2

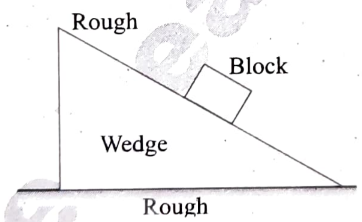
Displacement, Velocity and Acceleration of Center of Mass

Subjective Type

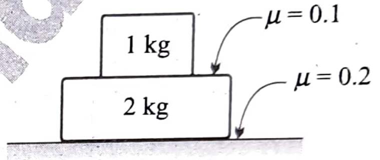


1. Two particles A and B of masses 1 kg and 2 kg respectively are projected in the same vertical line as shown in the figure with speeds u_A = 200 m/s and u_B = 85 m/s respectively. Initially they were 90 m apart. Find the maximum height attained by the centre of mass of the system of particles A and B, from the initial position of centre of mass of the system. Assume that none of these particles collide with the ground in that duration Take g = 10 m/s^2.
2. An object A is dropped from the rest from the top of a 30 m high building and at the same moment another object B is projected vertically upwards with an initial speed of 15 m/s from the base of the building. Mass of the object A is 2 kg while mass of the object B is 4 kg. Find the maximum height above the ground level attained by the centre of mass of the A and B system (take g = 10 m/s^2)

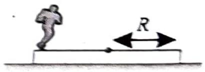
Single Correct Answer Type



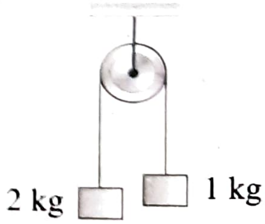
3. When a block is placed on a wedge as shown in the figure, the block starts sliding down and the wedge also start sliding on ground. All surfaces are rough. The centre of mass of (wedge + block) system will move
   (a) leftward and downward.
   (b) right ward and downward.
   (c) leftward and upwards.
   (d) only downward.
4. An explosive of mass 18 kg is located at position vector, $\vec{r}_0 = (6\hat{i} + 14\hat{j} + 20\hat{k})$ m in gravity free space. It breaks into four parts of masses 5 kg, 3 kg, 4 kg and 6 kg respectively. After sometime the position vectors of first three parts are $\vec{r}_1 = (10\hat{i} + 20\hat{j} + 9\hat{k})$ m $\vec{r}_2 = (8\hat{i} + 18\hat{j} + 25\hat{k})$ m and $\vec{r}_3 = (4\hat{i} + 10\hat{j} + 20\hat{k})$ m respectively. The position of the fourth part at that time will be
   (a) $\left(3\hat{i} - \frac{29}{3}\hat{j} + \frac{80}{3}\hat{k}\right)$ m (b) $\left(6\hat{i} - \frac{29}{3}\hat{j} + \frac{80}{3}\hat{k}\right)$ m
   (c) $\left(3\hat{i} + \frac{29}{3}\hat{j} + \frac{80}{3}\hat{k}\right)$ m (d) $\left(3\hat{i} + \frac{29}{3}\hat{j} - \frac{80}{3}\hat{k}\right)$ m
5. Both the blocks shown in the given arrangement are given together have a horizontal velocity towards right. If a_{cm} be the subsequent acceleration of the centre of mass of the system of blocks, then a_{cm} equals:



   (a) 0 m/s^2 (b) 5/3 m/s^2 (c) 7/3 m/s^2 (d) 2 m/s^2
6. The centre of mass of two masses m and m' moves by distance $\frac{x}{5}$ when mass m is moved by distance x and m' is kept fixed. The ratio $\frac{m'}{m}$ is
   (a) 2 (b) 4
   (c) 1/4 (d) None of these

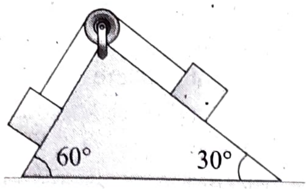


7. A disc of mass 'm' and radius R is placed on a smooth horizontal floor such that the plane surface of the disc is in contact with the floor. A man of mass $m/2$ stands on the disc at its periphery. The man starts walking along the periphery of the disc. The size of the man is negligible as compared to the size of the disc. Then the centre of disc.
   (a) moves along a circle of radius $R/3$
   (b) moves along a circle of radius $R/2$
   (c) moves along a circle of radius R
   (d) does not move along a circle



8. Two blocks of masses 2 kg and 1 kg respectively are tied to the ends of a string which passes over a light frictionless pulley. The masses are held at rest at the same horizontal level and then released.
   The distance traversed by centre of mass in 2 seconds is (g = 10 m/s^2)
   (a) 1.42 m (b) 2.22 m (c) 3.12 m (d) 3.33 m

9. Two blocks of equal mass are tied with a light string which passes over a massless pulley as shown in the figure.

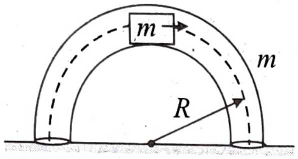


The magnitude of acceleration of centre of mass of both the blocks is (neglect friction everywhere)

(a) $\left(\frac{\sqrt{3}-1}{4\sqrt{2}}\right)g$ (b) $\left(\frac{\sqrt{3}+1}{4\sqrt{2}}\right)g$

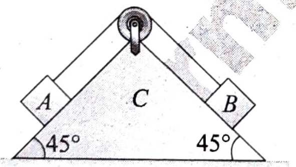
(c) $\left(\frac{\sqrt{3}-1}{2\sqrt{2}}\right)g$ (d) $\left(\frac{\sqrt{3}+1}{2\sqrt{2}}\right)g$

10. In a vertical plane inside a smooth hollow thin tube a block of same mass as that of tube is released as shown in the figure. When it is slightly disturbed it moves towards right. By the time the block reaches the right end of the tube, then the displacement of the tube will be (where 'R' is mean radius of tube). Assume that the tube remains in vertical plane. (Horizontal plane is smooth)



(a) $\frac{2R}{\pi}$ (b) $\frac{4R}{\pi}$ (c) $\frac{R}{2}$ (d) R

11. A system of two blocks A and B and a wedge C is released from the rest as shown in the figure. Masses of the blocks and the wedge are m, $2m$ and $2m$ respectively.

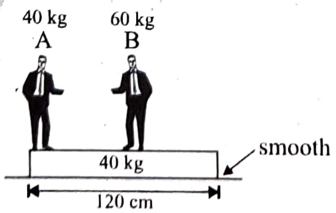


The displacement of wedge C when block B slides down the plane, a distance 10 cm is (neglect friction)

(a) $5\sqrt{2}$ cm (b) $3\sqrt{2}$ cm

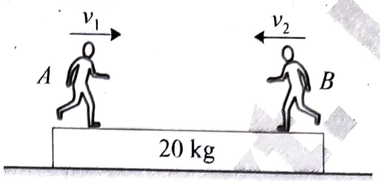
(c) 4 cm (d) $\frac{5}{\sqrt{2}}$ cm

12. Two men 'A' and 'B' are standing on a plank. 'B' is at the middle of the plank and 'A' is the left end of the plank. System is initially at rest and masses are as shown in the figure. 'A' and 'B' starts moving such that the position of 'B' remains fixed with respect to ground, then 'A' meets 'B'. Then the point where A meets B is located at:



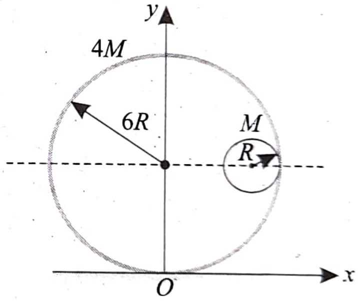
(a) the middle of the plank
(b) 30 cm from the left end of the plank
(c) the right end of the plank
(d) None of these

13. In the figure shown, the system is at rest initially. Two persons 'A' and 'B' of masses 40 kg each move with speeds v_1 and v_2 respectively towards each other on a plank lying on a smooth horizontal surface as shown in the figure. Plank travels a distance of 20 m towards right direction in 5 sec. (Here v_1 and v_2 are given with respect to the plank). Then



(i) $v_1 = 10$ m/s, $v_2 = 0$ m/s
(ii) $v_1 = 15$ m/s, $v_2 = 5$ m/s
(iii) $v_1 = 20$ m/s, $v_2 = 10$ m/s
(a) only (i) and (iii) are possible
(b) All (i), (ii) and (iii) are not possible
(c) only (ii) and (iii) are possible
(d) All (i), (ii) and (iii) are possible

14. A small sphere of radius R held against the inner surface of a smooth spherical shell of radius $6R$ as shown in the figure. The masses of the shell and small spheres are $4M$ and M respectively.

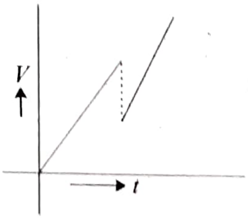


This arrangement is placed on a smooth horizontal table. The small sphere is now released. The x-coordinate of the centre of the shell when the smaller sphere reached the other extreme position is

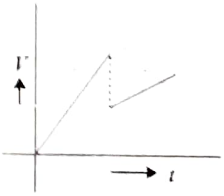
(a) R (b) $2R$ (c) $3R$ (d) $4R$

15. Two balls of the same mass are released simultaneously from heights h and $2h$ from the ground level. The balls collide with the floor and stick to it. Then the velocity–time graph of centre of mass of the two balls is best represented by:

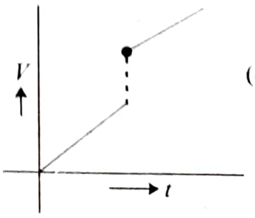
(a)



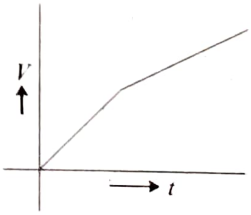
(b)



(c)



(d)



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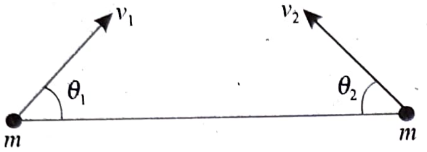
Multiple Correct Answers Type

16. Two particles of equal mass m are projected from the ground with speed v_1 and v_2 at angles θ_1 and θ_2 as shown in the figure.



The centre of mass of the two particles

(a) will move in a parabolic path for any values of v_1 and v_2, θ_2 and θ_2

(b) can move in a vertical line

(c) can move in a horizontal line

(d) will move in a straight line if $v_i \cos\theta_1 = v_2 \cos\theta_2$

17. Which of the following are correct?

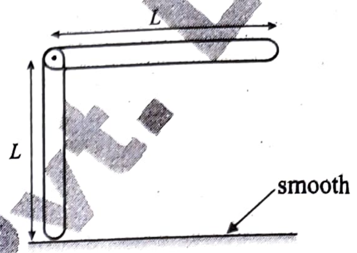
(a) If centre of mass of three particles is at rest, and it is known that two of them are moving along different lines then the third particle must also be moving.

(b) If centre of mass remains at rest, then net work done by the forces acting on the system must be zero.

(c) If centre of mass remains at rest, then net external force must be zero

(d) If center of mass of a sphere of particle is moving there must be net external force should act on the system.

18. Two identical rods are joined at one of their ends by a pin. Joint is smooth and rods are free to rotate about the joint. Rods are released in vertical plane on a smooth surface as shown in the figure. The displacement of the joint from its initial position to the final position is (i.e. when the rods lie straight on the ground):



(a) $\frac{L}{4}$ (b) $\frac{\sqrt{17}}{4}L$ (c) $\frac{\sqrt{5}\,L}{2}$ (d) none of these

Answers Key

Subjective Type

1. 5 m **2.** 15 m

Single Correct Answer Type

3. (b) **4.** (c) **5.** (d) **6.** (b) **7.** (a) **8.** (b) **9.** (a) **10.** (c) **11.** (b) **12.** (c)
13. (b) **14.** (b) **15.** (b)

Multiple Correct Answers Type

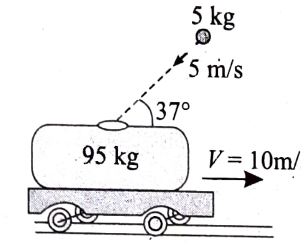
16. (b, d) **17.** (a, c) **18.** (b, d)

DPP 1.3

Conservation of Linear Momentum and Mechanical Energy

Subjective Type

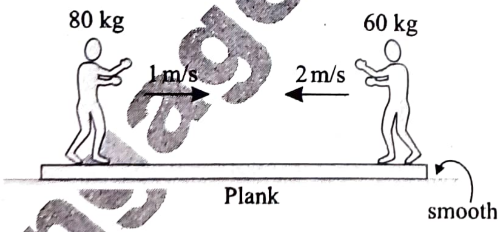
1. A rail wagon of mass 95 kg is moving with velocity = 10 m/s on frictionless rails. A body of mass 5 kg is thrown into the wagon with velocity 12.5 m/s as shown in the figure. The body collides inside with the walls of the wagon and due to internal losses it comes at rest with respect to wagon. Find the velocity of the wagon when the body comes to rest w.r.t. wagon. [Assume that the velocity of wagon and the object are in the same plane].



Single Correct Answer Type

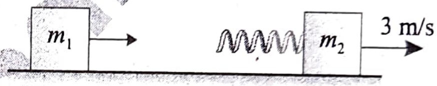
2. Two trains A and B are running in the same direction on parallel rails such that 'A' is faster than 'B'. Packets of equal weight are transferred between them. What will happen due to this?
   (a) A will be accelerated but B will be retarded.
   (b) B will be accelerated but A will be retarded.
   (c) There will be no change in A but B will be accelerated.
   (d) There will be no change in B, but A will be accelerated.

3. Two men of masses 80 kg and 60 kg are standing on a wood plank of mass 100 kg that has been placed over a smooth surface. If both the men start moving toward each other with speeds 1 m/s and 2 m/s respectively. The velocity of the plank by which it starts moving is



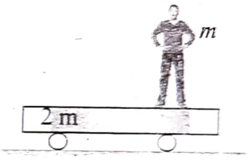
   (a) $\frac{1}{6}$ m/sec towards right
   (b) $\frac{1}{6}$ m/sec towards left
   (c) $\frac{2}{5}$ m/sec towards right
   (d) $\frac{2}{5}$ m/sec towards left

4. A block of mass $m_1 = 2$ kg slides on a frictionless table with speed of 10 m/s. In front of it, another block of mass $m_2 = 5$ kg is moving with speed 3 m/s in the same direction. A massless spring of spring constant $k = 1120$ N/m is attached on the backside of m_2 as shown. The maximum compression of the spring in cm when the blocks collide is



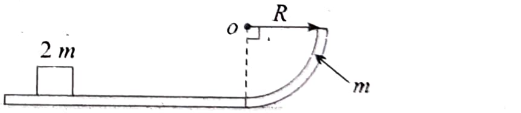
   (a) 25 cm (b) 10 cm (c) 2.5 cm (d) 5 cm

5. A man is standing on a cart of mass double the mass of the man. Initially cart is at rest on the smooth ground. Now man jumps with relative velocity 'v' horizontally towards right with respect to cart. The work done by man during the process of jumping is



   (a) mv^2 (b) $\frac{mv^2}{2}$ (c) $\frac{mv^2}{4}$ (d) $\frac{mv^2}{3}$

6. Mass $2m$ is kept on a smooth circular track of mass m which is kept on a smooth horizontal surface. The circular track is given a horizontal velocity towards left and released. The maximum height reached by $2m$ will be

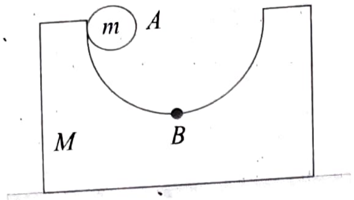


   (a) $\frac{R}{4}$ (b) $\frac{R}{2}$ (c) $\frac{R}{3}$ (d) $\frac{2R}{3}$

7. A gun fires a shell and recoils horizontally. If the shell travels along the barrel with speed v, the ratio of speed with which the gun recoils if (i) the barrel is horizontal (ii) inclined at an angle of 30° with horizontal is
   (a) 1 (b) $\frac{2}{\sqrt{3}}$ (c) $\frac{\sqrt{3}}{2}$ (d) $\frac{1}{2}$

8. A block of mass $M = 2$ kg with a semicircular track of radius $R = 1.1$ m rests on a horizontal frictionless surface.

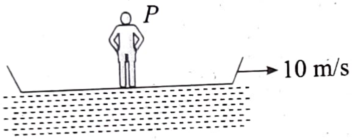
A uniform cylinder of radius r = 10 cm and mass m = 1.0 kg is released from rest from the top point a. The cylinder slips on the semicircular frictionless track. The speed of the block when the cylinder reaches the bottom of the track at B is (g = 10 m/s^2)



(a) $\sqrt{\frac{10}{3}}$ m/s (b) $\sqrt{\frac{4}{3}}$ m/s

(c) $\sqrt{\frac{5}{2}}$ m/s (d) $\sqrt{10}$ m/s

9. A person P of mass 50 kg stands at the middle of a boat of mass 100 kg moving at a constant velocity 10 m/s with no friction between water and boat and also the engine of the boat is shut off. With what velocity (relative to the boat surface) should the person move so that the boat comes to rest. Neglect friction between water and boat.

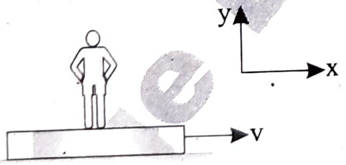


(a) 30 m/s towards right (b) 20 m/s towards right
(c) 30 m/s towards left (d) 20 m/s towards left

10. A cannon shell moving along a straight line bursts into two parts. Just after the burst one part moves with momentum 40 Ns making an angle 30° with the original line of motion. The minimum momentum of the other part of shell just after the burst is:

(a) 0 Ns (b) 10 Ns (c) 20 Ns (d) 17.32 Ns

11. A man and a plank of the same mass are moving with a velocity v along positive x-axis. At the same time man jumps along negative x-axis with a velocity v with respect to ground, then the speed of the plank is:



(a) v (b) $2v$ (c) $3v$ (d) none of these

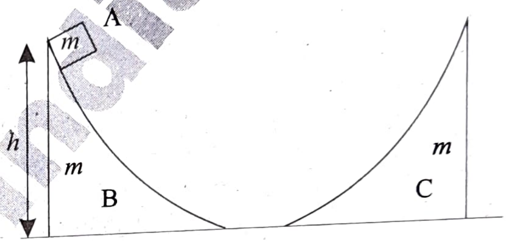
Multiple Correct Answers Type

12. If the resultant force on a system of particles is non-zero, then:

(a) the linear momentum of the system must increase.
(b) the velocity of the centre of mass of the system must change.
(c) the distance of the centre of mass may remain constant from a fixed point.
(d) kinetic energy of all particles must either increase simultaneously or decrease simultaneously.

Comprehension Type

Block A is placed on wedge B at a height h above the ground. Block and the two wedges are all of the same mass m. Neglect friction everywhere:



13. Find velocity of B when A has slide down from it:

(a) $\sqrt{gh}$ (b) $\sqrt{\frac{gh}{2}}$

(c) $\frac{\sqrt{gh}}{2}$ (d) None of these

14. Find maximum height up to which block A rises on wedge C:

(a) h (b) $\frac{h}{2}$

(c) $\frac{h}{4}$ (d) None of these

15. Find velocity of A when it has slide down to ground from wedge C:

(a) 0 (b) $\sqrt{\frac{gh}{2}}$

(c) $\sqrt{\frac{gh}{4}}$ (d) None of these

Answers Key

Subjective Type

1. 9 m/s

Single Correct Answer Type

2. (b) 3. (b) 4. (a) 5. (d) 6. (c)
7. (b) 8. (a) 9. (a) 10. (c) 11. (c)

Multiple Correct Answers Type

12. (b, c)

Comprehension Type

13. (a) 14. (c) 15. (a)

DPP 1.4

Head-on Collision

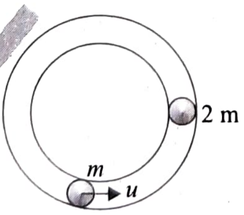
Single Correct Answer Type

1. In a collision between two solid spheres, velocity of separation along the line of impact (assume no external forces act on the system of two spheres during impact):
   (a) cannot be greater than velocity of approach
   (b) cannot be less than velocity of approach
   (c) cannot be equal to velocity of approach
   (d) none of these

2. Two small spheres of equal mass, and heading towards each other with equal speeds, undergo a head-on collision (no external force acts on system of two spheres). Then which of the following statement is correct?
   (a) Their final velocities must be zero.
   (b) Their final velocities may be zero.
   (c) Each must have a final velocity equal to the other's initial velocity.
   (d) Their velocities must be reduced in magnitude

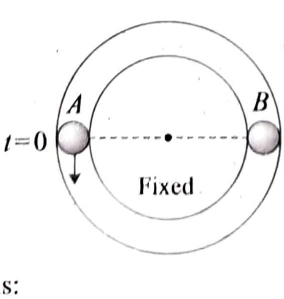
3. A ball of mass m moves towards a moving wall of infinite mass with a speed 'v' along the normal to the wall. The speed of the wall is 'u' toward the ball. The speed of the ball after 'elastic' collision with wall is:
   (a) $u + v$ away from the wall
   (b) $2u + v$ away from the
   (c) $|u - v|$ away from the wall
   (d) $|v - 2u|$ away from the wall

4. Two masses 'm' and '$2m$' are placed in fixed horizontal circular smooth hollow tube as shown. The mass 'm' is moving with speed 'u' and the mass '$2m$' is stationary. After their first collision, the time elapsed for next collision. (Coefficient of restitution $e = 1/2$)



   (a) $\frac{2\pi r}{u}$ (b) $\frac{4\pi r}{u}$ (c) $\frac{3\pi r}{u}$ (d) $\frac{12\pi r}{u}$

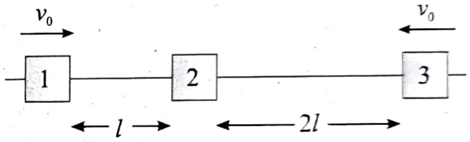
5. Particle 'A' moves with speed 10 m/s in a frictionless circular fixed horizontal pipe of radius 5 m and strikes with 'B' of double mass that of A. Coefficient of restitution is 1/2 and particle 'A' starts its journey at $t = 0$. The time at which second collision occurs is:



   (a) $\frac{\pi}{2}$ s (b) $\frac{2\pi}{3}$ s (c) $\frac{5\pi}{2}$ s (d) 4π s

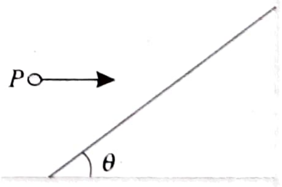
6. A heavy elevator is moving upwards with constant velocity 5 m/sec. At time $t = 0$ a ball situated at a distance of 100 m from the elevator is dropped. Find the velocity of ball just after the collision (elastic). (Use $g = 10$ m/s^2)
   (a) 10 m/s (b) 20 m/s (c) 40 m/s (d) 50 m/s

7. Three small bodies of identical masses can move along a straight line. The central body (2) is initially at rest and bodies 1 and 3 are at a distance and from the central body respectively. Bodies 1 and 3 move towards body 2 with speeds v_0 each. The collision between 1 and 2 is perfectly elastic and the collision between body 2 and 3 is perfectly inelastic. After all the collisions are over:



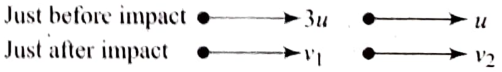
   (a) all the bodies come to rest
   (b) the body 1 moves towards left, bodies 2 and 3 move towards right
   (c) body 2 remains at rest and other bodies 1 and 3 turn back
   (d) all the bodies move towards right.

8. In the figure shown a particle P strikes the inclined smooth plane horizontally and rebounds vertically. If the angle θ is 60°, then the coefficient of restitution is:



   (a) $\frac{1}{3}$ (b) $\frac{1}{\sqrt{3}}$ (c) $\frac{1}{2}$ (d) 1

9. The smooth objects with a coefficient of restitution e collides directly and bounce as shown



Newton's law of restitution gives

(a) $e \times 4u = v_2 + v_1$
(b) $e \times 2u = v_1 - v_2$
(c) $e \times 2u = v_2 - v_1$
(d) it cannot be applied as the masses are not known.

10. A particle of mass 0.1 kg moving with an initial speed v collides with another particle of the same mass kept at rest. If after collision total energy becomes 0.2 J. Then
(a) minimum value of v is 2 m/s
(b) maximum value of v is 4 m/s
(c) minimum value of v is 3 m/s
(d) maximum value of v is 6 m/s

11. A ball of m approaches a wall of mass M ($>> m$) with speed 4 m/s along the normal to the wall. The speed of wall is 1 m/s towards the ball. The speed of the ball after an elastic collision with the wall is
(a) 5 m/s away from the wall
(b) 9 m/s away from the wall
(c) 3 m/s away from the wall
(d) 6 m/s away from the wall

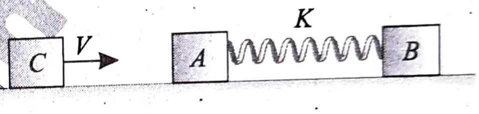
12. A ball strikes a horizontal floor at an angle $\theta = 45°$. The coefficient of restitution between the ball and the floor is $e = \frac{1}{2}$. The fraction of its kinetic energy lost in collision is
(a) 5/8 (b) 3/8 (c) 3/4 (d) 1/4

13. In one-dimensional collision of two particle velocities are interchanged when
(i) collision is elastic and masses are unequal
(ii) collision is inelastic but masses are unequal
Select the correct alternative
(a) only (i) is correct
(b) only (ii) is correct
(c) both (i) and (ii) are correct
(d) both (i) and (ii) are wrong

14. A particle of mass m collides with a stationary particle and continues to move at an angle of 45° with respect to the original direction. The second particle also recoils at an angle of 45° to this direction. The mass of the second particle is (collision is elastic)
(a) m (b) $\sqrt{2}\,m$ (c) $\frac{m}{\sqrt{2}}$ (d) $\frac{m}{2}$

Multiple Correct Answers Type

15. Two blocks A and B each of mass m are connected to a massless spring of natural length L and spring constant K. The blocks are initially resting on a smooth horizontal floor with the spring at its natural length as shown in the figure. A third identical block C also of mass m moves on the floor with speed v along the line joining A and B and collides elastically with A, then



(a) the K.E. of the A–B system at maximum compression of the spring is zero
(b) the K.E. of the A–B system at maximum compression of the spring is $mv^2/4$
(c) the maximum compression of the spring is $v\sqrt{(m/K)}$
(d) the maximum compression of the spring is $v\sqrt{(m/2K)}$

Answers Key

Single Correct Answer Type

1. (a) 2. (b) 3. (b) 4. (b) 5. (c)
6. (d) 7. (a) 8. (a) 9. (c) 10. (a)
11. (d) 12. (b) 13. (a) 14. (a)

Multiple Correct Answers Type

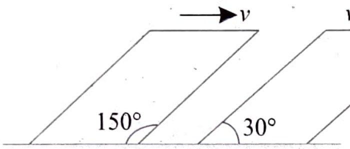
15. (b, d)

DPP 1.5

Oblique Collision

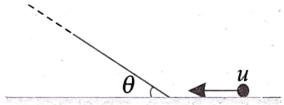
Single Correct Answer Type

1. Two blocks moving towards each other collide as shown in the figure. Find out the angle between the line of motion and the line of impact.



(a) 30° (b) 60° (c) 90° (d) zero

2. A particle of mass m is given initial speed u as shown in the figure. It transfers to the fixed inclined plane without a jump, that is, its trajectory changes sharply from the horizontal line to the inclined line. All the surfaces are smooth and $90° \geq \theta > 0°$. Then the height to which the particle shall rise on the inclined plane (assume the length of the inclined plane to be very large)



(a) increases with increase in θ
(b) decreases with increase in θ
(c) is independent of θ
(d) data insufficient

3. Two objects of the same mass and with the same initial speed, moving in a horizontal plane, collide and move away together at half their initial speed after the collision. The angle between the initial velocities of the objects is

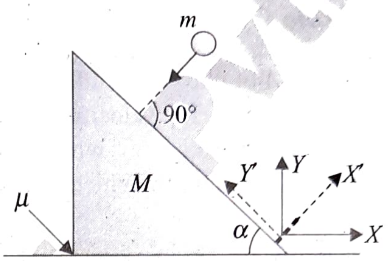
(a) 120° (b) 90° (c) 60° (d) 30°

4. Two billiard balls of the same size and mass are in contact on a billiard table. A third ball of the same size and the mass strikes, then symmetrically and remains at rest after the impact. The coefficient of restitution between the balls is

(a) $\frac{1}{2}$ (b) $\frac{3}{2}$

(c) $\frac{2}{3}$ (d) $\frac{3}{4}$

5. A ball of mass m strikes the inclined face of the wedge normally with speed v_0. The wedge is at rest on a rough horizontal surface before collision. The conservation of momentum is applicable for

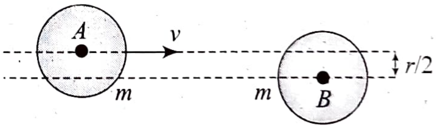


(i) m as system, along Y'
(ii) M as system, along Y'
(iii) $(M + m)$ as system, along X
(iv) $(M + m)$ as system, along Y

Which of the following statement/statements is correct?

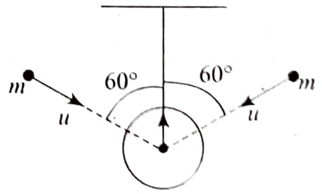
(a) (i) only (b) (i) and (ii) only
(c) (iii) only (d) (iii) and (iv) only

6. A disk A of radius r moving on perfectly smooth surface at a speed v undergoes an elastic collision with an identical stationary disk B. Find the velocity of the disk B after collision if the impact parameter is $r/2$ as shown in the figure



(a) $\frac{v\sqrt{15}}{4}$ (b) $\frac{v}{4}$ (c) $\frac{v}{2}$ (d) $\frac{\sqrt{3}v}{2}$

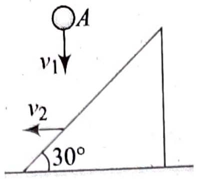
7. A bob of mass 10 M is suspended through an inextensible string of length l. When the bob is at rest at the equilibrium position, two particles of mass m each moving with velocity u making an angle 60° with the string strike and get simultaneously attached to the bob. What is the value of impulsive tension (J_{tension}) in the string during the impact?



(a) zero (b) 2 mu (c) mu (d) 12 mu

8. A ball A is falling vertically downwards with velocity v_1. It strikes elastically with a wedge moving horizontally with

velocity v_2 as shown in the figure. What must be the ratio $\frac{v_1}{v_2}$ so that the ball bounces back in vertically upwards direction relative to wedge?



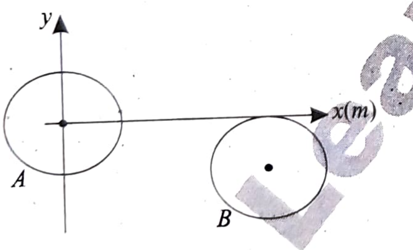
(a) $\sqrt{3}$ (b) $\frac{1}{\sqrt{3}}$ (c) 2 (d) $\frac{1}{2}$

Multiple Correct Answers Type

9. A smooth sphere A of mass m collides elastically with an identical sphere B at rest. The velocity of A before collision is 8 m/s in a direction making 60° with the line joining the centres at the time of impact. Which of the following is/are possible?
(a) the sphere A comes to rest after collision
(b) the sphere B will move with a speed of 8 m/s after collision
(c) the directions of motion of A and B after collision are at right angles
(d) the speed of B after collision is 4 m/s

Comprehension Type

Two smooth balls A and B, each of mass m and radius R, have their centres at $(0, 0, R)$ and at $(5R, -R, R)$ respectively, in a coordinate system as shown. Ball A, moving along positive x-axis, collides with ball B. Just before the collision, speed of ball A is 4 m/s and ball B is stationary. The collision between the balls is elastic.

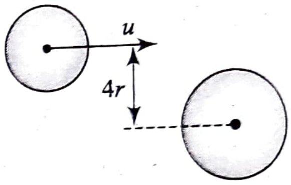


10. Velocity of the ball A just after the collision is:
(a) $(i+\sqrt{3}j)$ m/s (b) $(i-\sqrt{3}j)$ m/s
(c) $(2i+\sqrt{3}j)$ m/s (d) $(2i+2j)$ m/s

11. Impulse of the force exerted by A on B during the collision is equal to
(a) $(\sqrt{3}mi+3mj)\frac{\text{kgm}}{\text{s}}$ (b) $\left(\frac{\sqrt{3}}{2}mi-\sqrt{3}mj\right)\frac{\text{kgm}}{\text{s}}$
(c) $(3mi-\sqrt{3}mj)\frac{\text{kgm}}{\text{s}}$ (d) $(2\sqrt{3}mi+3j)\frac{\text{kgm}}{\text{s}}$

12. Coefficient of restitution during the collision is changed to $\frac{1}{2}$, keeping all other parameters unchanged. What is the velocity of the ball B after the collision?
(a) $\frac{1}{2}(3\sqrt{3}i+9j)$ m/s (b) $\frac{1}{4}(9i-3\sqrt{3}j)$ m/s
(c) $(6i+3\sqrt{3}j)$ m/s (d) $(6i-3\sqrt{3}j)$ m/s

A circular disc of mass '$2m$' and radius '$3r$' is resting on a flat frictionless surface. Another circular disc of mass 'm' and radius '$2r$', moving with a velocity 'u' hits the first disc as shown in the figure. The collision is elastic.



13. What is the tangential component of final velocity of the smaller disc?
(a) u (b) $\frac{u}{2}$ (c) $\frac{3u}{5}$ (d) $\frac{4u}{5}$

14. What is the magnitude of normal component of final velocity of the smaller disc?
(a) $\frac{u}{5}$ (b) $\frac{2u}{5}$ (c) $\frac{3u}{5}$ (d) $\frac{4u}{5}$

15. What is the final velocity of the heavier disc?
(a) $\frac{u}{5}$ (b) $\frac{2u}{5}$ (c) $\frac{3u}{5}$ (d) $\frac{4u}{5}$

Answers Key

Single Correct Answer Type

1. (b) **2.** (b) **3.** (a) **4.** (c) **5.** (a)
6. (a) **7.** (c) **8.** (b)

Multiple Correct Answers Type

9. (c, d)

Comprehension Type

10. (a) **11.** (c) **12.** (b) **13.** (d) **14.** (a)
15. (b)

CHAPTER 2

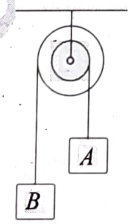
Rigid Body Dynamics I

DPP 2.1

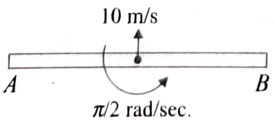
Rotational Kinematics

Subjective Type

1. A 0.6 m radius drum carrying the load A is rigidly attached to a 0.9 m radius pulley carrying the load B as shown. At the time $t = 0$, the load B moves with a velocity of 2 m/s (downward) and a constant acceleration of 3 m/s^2 (downward). Over the time interval, $0 \leq t \leq 2$ s, determine:
   (i) the number of revolutions executed by the pulley.
   (ii) the displacement of the load A.



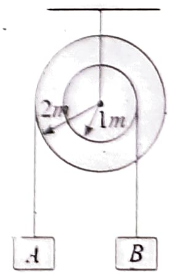
2. A uniform rod AB of length 4 m and mass 12 kg is thrown such that just after the projection, the centre of mass of the rod moves vertically upwards with a velocity 10 m/s and at the same time it is rotating with an angular velocity rad/sec about a horizontal axis passing through its mid-point. Just after the rod is thrown it is horizontal and is as shown in the figure. Find the acceleration (in m/sec^2) of the point A in m/s^2 when the centre of mass is at the highest point. (Take $g = 10$ m/s^2 and $\pi^2 = 10$)



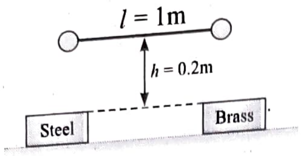
Single Correct Answer Type

3. The angular velocity of a rigid body about any point of that body is the same:
   (a) only in magnitude
   (b) only in direction
   (c) both in magnitude and direction necessarily
   (d) both in magnitude and direction about some points but not about all points.

4. In the pulley system shown, if the radii of the bigger and smaller pulleys are 2 m and 1 m respectively and the acceleration of block A is 5 m/s^2 in the downward direction, then the acceleration of block B will be:
   (a) 0 m/s^2 (b) 5 m/s^2
   (c) 10 m/s^2 (d) 5/2 m/s^2



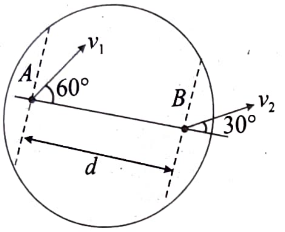
5. Two points of a rod move with velocities $3v$ and v perpendicular to the rod and in the same direction, separated by a distance 'r'. Then the angular velocity of the rod is:
   (a) $\frac{3v}{r}$ (b) $\frac{4v}{r}$ (c) $\frac{5v}{r}$ (d) $\frac{2v}{r}$



6. Two steel balls of equal diameter are connected by a rigid bar of negligible weight as shown and are dropped in the horizontal position from height h above the heavy steel and brass base plates. If the coefficient of restitution between the ball and steel base is 0.6 and that between the other ball and the brass base is 0.4. The angular velocity of the bar immediately after rebound is (Assume the two impacts are simultaneous).

(a) $\frac{2}{5}$rad/sec (b) $\frac{1}{5}$rad/sec

(c) $\frac{3}{5}$rad/sec (d) $\frac{1}{4}$rad/sec



7. Two points A and B on a disc have velocities v_1 and v_2 at some moment. Their directions make angles 60° and 30° respectively with the line of separation as shown in the figure. The angular velocity of disc is:

(a) $\frac{\sqrt{3}v_1}{d}$ (b) $\frac{v_2}{\sqrt{3}d}$ (c) $\frac{v_2 - v_1}{d}$ (d) $\frac{v_2}{d}$

8. When a person throws a meter stick, it is found that the centre of the stick is moving with speed 10 m/s and left end of stick with speed 20 m/s. Both points move vertically upwards at that moment. Then angular speed of the stick is:

(a) 20 rad/sec (b) 10 rad/sec

(c) 30 rad/sec (d) none of these

9. A ring of radius R rolls without slipping on a rough horizontal surface with a constant velocity. The radius of curvature of the path followed by any particle of the ring at the highest point of its path will be:

(a) R (b) $2R$ (c) $4R$ (d) none of these

Multiple Correct Answers Type

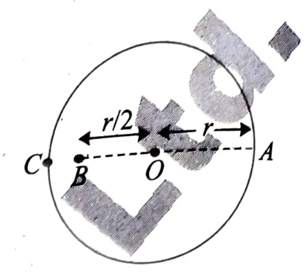
10. A rigid body is in pure rotation, that is, undergoing fixed axis rotation. Then which of the following statement(s) are true.

(a) You can find two points in the body in a plane perpendicular to the axis of rotation having same velocity.

(b) You can find two points in the body in a plane perpendicular to the axis of rotation having the same acceleration.

(c) Speed of all the particles lying on the curved surface of a cylinder whose axis coincides with the axis of rotation is the same.

(d) Angular speed of the body is the same as seen from any point in the body.



11. A particle is revolving in a circle of radius r and centre at 'O' with uniform angular velocity ω. Choose the correct option(s):

(a) the ratio of angular velocity at A about O and about B is 3 : 2.

(b) the angular velocity at A about all points O, B and C is the same.

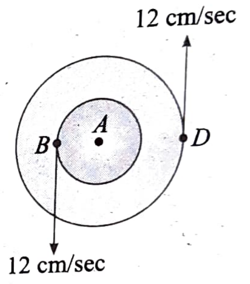
(c) the angular velocity at A about C is $\omega/2$.

(d) the velocity at A and C is the same.

Comprehension Type

For Q. 12 and 13

In a double pulley 2 cm radius inner pulley is rigidly attached to the 4 cm radius outer pulley. Knowing that each of the two cords is pulled at a constant speed of 12 cm/sec as shown in figure, determine:



12. The instantaneous centre of rotation of double pulley is

(a) 0.5 cm to the left of A.

(b) 1 cm to the right of A.

(c) 0.25 cm to the left of A.

(d) 0.75 cm to the right of A.

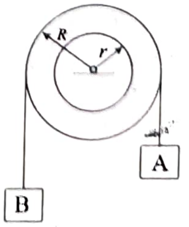
13. The velocity of the center of pulley A is

(a) 4 cm/s (b) 3 cm/s

(c) 2.5 cm/s (d) 5 cm/s

For Q. 14 and 15

A $r = 0.6$ m radius drum carrying the load A is rigidly attached to a $R = 0.9$ m radius pulley carrying the load B as shown. At the time $t = 0$, the load B moves with a velocity of 2 m/s (downward) and a constant acceleration of 3 m/s^2 (downward). Over the time interval $0 \le t \le 2$s,



14. The number of revolutions executed by the pulley.

(a) $\frac{25}{9\pi}$ (b) $\frac{50}{7\pi}$ (c) $\frac{50}{9\pi}$ (d) $\frac{25}{7\pi}$

15. The displacement of the load A.

(a) $\frac{20}{3}$ m (b) $\frac{10}{3}$ m (c) $\frac{20}{7}$ m (d) $\frac{20}{9}$ m

Answers Key

Subjective Type

1. (i) $\frac{50}{9\pi}$ (ii) $\frac{20}{3}$m **2.** 5 m/s^2

Single Correct Answer Type

3. (c) **4.** (d) **5.** (d) **6.** (a) **7.** (d)
8. (a) **9.** (c)

Multiple Correct Answers Type

10. (c, d) **11.** (a, c)

Comprehension Type

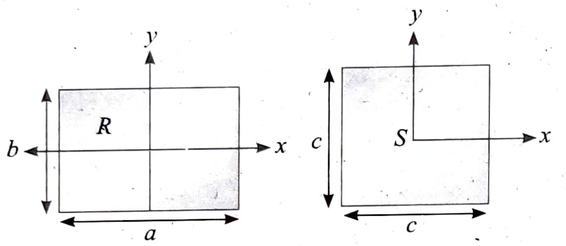
12. (b) **13.** (a) **14.** (c) **15.** (a)

DPP 2.2

Moment of Inertia

Subjective Type

1. Three identical rods, each of length l, are joined to form a rigid equilateral triangle. Find its radius of gyration about an axis passing through a corner and perpendicular to the plane of the triangle.
2. A uniform square plate S (side c) and a uniform rectangular plate R (sides b, a) have identical areas and masses.

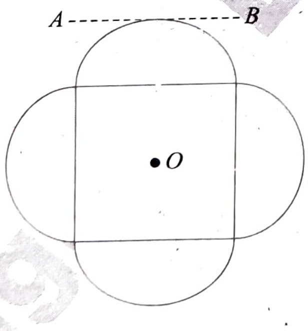


Show that

(a) $I_{xR} + I_{xS} < 1$ (b) $I_{yR}/I_{yS} > 1$

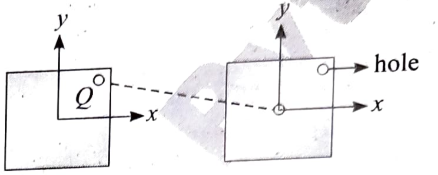
(c) $I_{zR}/I_{zS} > 1$

3. A symmetric lamina of mass M consists of a square shape with a semicircular section over each of the edge of the square as in the figure. The side of the square is $2a$. The moment of inertia of the lamina about an axis through its centre of mass and perpendicular to the plane is $1.6Ma^2$. Find the moment of inertia of the lamina about the tangent AB in the plane of lamina is.



Single Correct Answer Type

4. A uniform square plate has a small piece Q of an irregular shape removed and glued to the centre of the plate leaving a hole behind in the figure. The moment of inertia about the z-axis is then



(a) increased
(b) decreased
(c) the same
(d) changed in unpredicted manner

5. The moment of inertia of an elliptical disc of uniform mass distribution of mass 'm', major axis 'r', minor axis 'd' about its axis is:

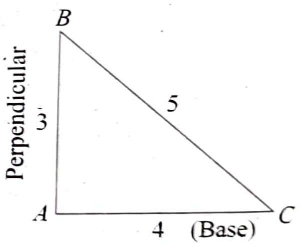
(a) $=\frac{mr^2}{2}$ (b) $=\frac{md^2}{2}$ (c) $>\frac{mr^2}{2}$ (d) $<\frac{mr^2}{2}$

6. The moment of inertia of a door of mass m, length $2l$ and width l about its longer side is

(a) $\frac{11\,ml^2}{24}$ (b) $\frac{5\,ml^2}{24}$

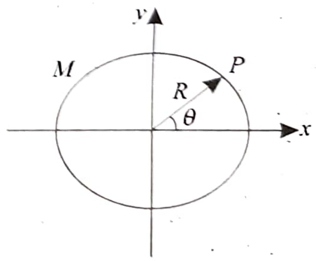
(c) $\frac{ml^2}{3}$ (d) none of these

7. Moment of inertia of uniform triangular plate about axis passing through sides AB, AC and BC are I_P, I_B and I_H respectively and about an axis perpendicular to the plane and passing through point C is I_C. Then:



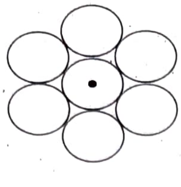
(a) $I_C > I_P > I_B > I_H$ (b) $I_H > I_B > I_C > I_P$
(c) $I_P > I_H > I_B > I_C$ (d) none of these

8. A ring of mass M and radius R lies in x-y plane with its centre at origin as shown. The mass distribution of ring is nonuniform such that at any point P on the ring, the mass per unit length is given by $\lambda = \lambda_0 \cos^2\theta$ (where λ_0 is a positive constant). Then the moment of inertia of the ring about z-axis is:



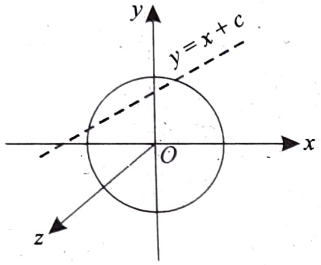
(a) MR^2 (b) $\frac{1}{2}MR^2$ (c) $\frac{1}{2}\frac{M}{\lambda_0}R$ (d) $\frac{1}{\pi}\frac{M}{\lambda_0}R$

9. Seven identical discs are arranged in a hexagonal, planar pattern so as to touch each neighbor, as shown in the figure. Each disc has mass m and radius r. What is the moment of inertia of the system of seven disks about an axis passing through the centre of central disk and normal to plane of all disks?



(a) $\frac{7}{2}mr^2$ (b) $\frac{13}{2}mr^2$ (c) $\frac{29}{2}mr^2$ (d) $\frac{55}{2}mr^2$

10. A uniform disc of radius R lies in the x-y plane, with its centre at origin. Its moment of inertia about z-axis is equal to its moment of inertia about line $y = x + c$. The value of c will be

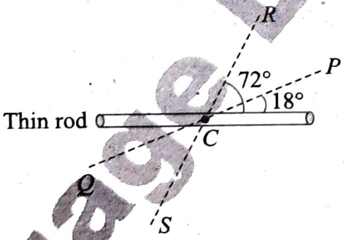


(a) $-\frac{R}{2}$ (b) $\pm\frac{R}{\sqrt{2}}$ (c) $\frac{+R}{4}$ (d) $-R$

11. The moment of inertia of a hollow cubical box of mass M and side a about an axis passing through the centres of two opposite faces is equal to

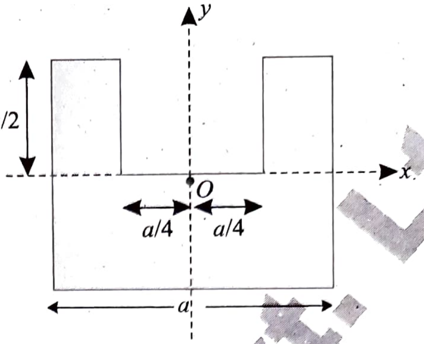
(a) $\frac{5Ma^2}{3}$ (b) $\frac{5Ma^2}{6}$ (c) $\frac{5Ma^2}{12}$ (d) $\frac{5Ma^2}{18}$

12. The moment of inertias of a uniform thin rod of mass m and length L about the axis PQ and RS passing through centre of rod C and in the plane of the rod are I_{PQ} and I_{RS} respectively. Then $I_{PQ} + I_{RS}$ is equal to



(a) $\frac{ml^2}{3}$ (b) $\frac{ml^2}{2}$ (c) $\frac{ml^2}{4}$ (d) $\frac{ml^2}{12}$

13. A square plate of edge $a/2$ is cut out from a uniform square plate of edge 'a' as shown in the figure. The mass of the remaining portion is M. The moment of inertia of the shaded portion about an axis passing through 'O' (centre of the square of side a) and perpendicular to plane of the plate is:

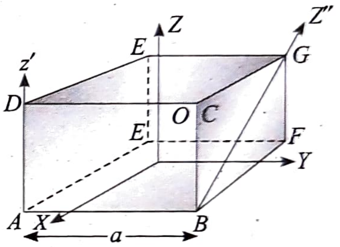


(a) $\frac{9}{64}Ma^2$ (b) $\frac{3}{16}Ma^2$

(c) $\frac{5}{12}Ma^2$ (d) $\frac{Ma^2}{6}$

Multiple Correct Answers Type

14. With reference to the figure of a cube of edge a and mass m, state which of the following statements are correct. (0 is the centre of the cube.)



(a) The moment of inertia of cube about z-axis is $I_z = I_x + I_y$

(b) The moment of inertia of cube about z'-axis is

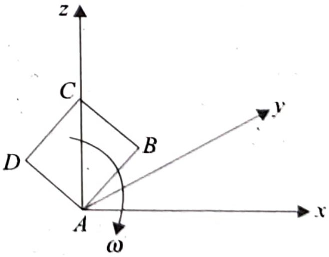
$$I_{z'} = I_z + \frac{ma^2}{2}$$

(c) The moment of inertia of cube about z'' axis is

$$= I_z + \frac{ma^2}{2}$$

(d) $I_x = I_y$

15. A square plate may either rotate in (x-z) plane about point A or may rotate by falling towards (x-y) plane. If I_1 and I_2 are moment of inertias in the two cases respectively. Find the correct option.



(a) $I_1 = \frac{5}{6}Ml^2$ (b) $I_1/I_2 = 2$

(c) $I_1/I_2 = 5/4$ (d) $I_1/I_2 = 1/2$

Answers Key

Subjective Type

1. $l/\sqrt{2}$ **3.** $4.8Ma^2$

Single Correct Answer Type

4. (b) **5.** (d) **6.** (c) **7.** (a) **8.** (a)
9. (d) **10.** (b) **11.** (d) **12.** (d) **13.** (b)

Multiple Correct Answers Type

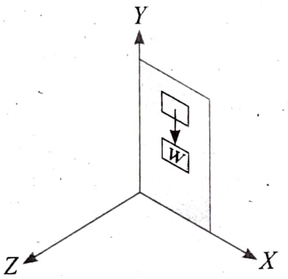
14. (b, d) **15.** (a, c)

DPP 2.3

Concept of Torque and Rotation Equilibrium

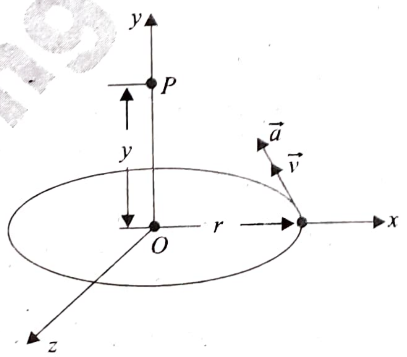
Concept Based

1. The vector sum of a system of non-collinear forces acting on a rigid body is given to be non-zero. If the vector sum of all the torques due to the system of forces about a certain point is found to be zero, does this mean that it is necessarily zero about any arbitrary point?
2. A door is hinged at one end and is free to rotate about a vertical axis (see figure). Does its weight cause any torque about this axis? Give reason for your answer.



Subjective Type

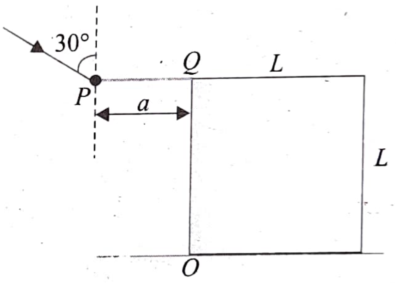
3. Two cylindrical hollow drums of radii R and $2R$ and of a common height h are rotating with angular velocities ω (anticlockwise) and ω (clockwise), respectively. Their axes, fixed are parallel and in a horizontal plane separated by $3R + \delta$. They are now brought in contact ($\delta \to 0$)
   (a) Show the frictional forces just after contact.
   (b) Identify forces and torques external to the system just after contact.
   (c) What would be the ratio of final angular velocities when friction ceases?
4. A particle of mass m moves in a circular path of radius r in xz plane with a constant magnitude of acceleration a. When the particle acquires a speed v:



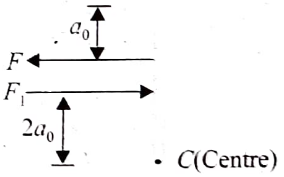
   (a) Find the net torque of the forces acting on the particle about a point P situated at a distance "y" on y-axis.
   (b) What are the components of the net torque about P along x, y and z-axes, assuming that the particle crosses the x-axis when it acquires the speed v?

Single Correct Answer Type

5. A cubical block of side L and mass m is placed on a horizontal floor. In the arrangement as shown, a force F is applied at the end of the plane sheet PQ which is firmly attached with the block. What should be the minimum value of PQ so that block may be tipped about an edge?



   (a) $L/\sqrt{3}$ (b) $L\sqrt{2}$ (c) $L\sqrt{2}/3$ (d) $L\sqrt{3}/\sqrt{2}$
6. A thin uniform rod of mass m and length L is moving translationally with acceleration 'a' due to two antiparallel forces, as shown. One of the forces is F. Find the maximum value of acceleration for which rod may move translationally.



   (a) $3F/2m$ (b) $2F/3m$
   (c) $F/3m$ (d) $F/2m$
7. The mass of a sphere placed on a smooth horizontal surface is distributed non-uniformly. A horizontal force equal to weight of sphere is applied at a distance 'a' from centre of the sphere for a short time. The sphere is rotated by an angle θ, but it behaves as if in stable equilibrium. Find the distance between centre and CG of the sphere:
   (a) $a \tan\theta$ (b) $a \cot\theta$
   (c) $a \sec\theta$ (d) $a\ \mathrm{cosec}\ \theta$

Multiple Correct Answers Type

8. The net external torque on a system of particles about an axis is zero. Which of the following are compatible with it?

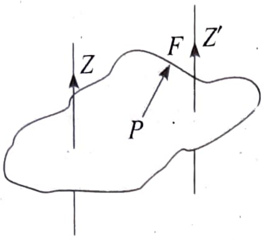
(a) The forces may be acting radially from a point on the axis

(b) The forces may be acting on the axis of rotation

(c) The forces may be acting parallel to the axis of rotation

(d) The torque caused by some forces may be equal and opposite to that caused by other forces

9. Figure shows a lamina in xy-plane. Two axes z and z' pass perpendicular to its plane. A force F acts on the plane of lamina at point P as shown. Which of the following are true? (The point P is closer to z'-axis than the z-axis.)



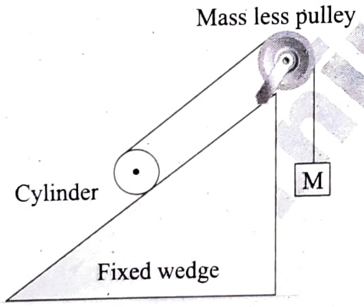
(a) Torque τ caused by F about z-axis is along $-\hat{k}$

(b) Torque τ' caused by F about z'-axis is along $-\hat{k}$

(c) Torque τ caused by F about z-axis is greater in magnitude than that about z-axis

(d) Total torque is given by $\tau = \tau + \tau'$

10. A cylinder and a variable mass M are arranged on a fixed wedge using a light string and a massless pulley. There is enough friction between cylinder and the wedge to prevent any slipping.



(a) Only one value of M is possible for which cylinder can remain in equilibrium.

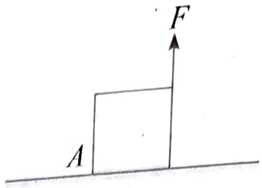
(b) There is a range of value of M for which cylinder can remain in equilibrium.

(c) For a certain value of M, the cylinder starts to roll up the plane. In this situation, magnitude of friction force on the cylinder by the wedge will be greater than tension in the string

(d) For a certain value of M, the cylinder starts to roll down the plane. In this situation, magnitude of friction force on the cylinder by the wedge will be greater than tension in the string

Matching Column Type

11. A uniform cube of mass m and side a is placed on a frictionless horizontal surface. A vertical force F is applied to the edge as shown in the figure. Match the following (most appropriate choice)

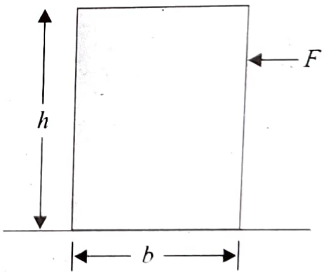


	Column-I		Column-II
(p)	$mg/4 < F < mg/2$	(i)	Cube will move up.
(q)	$F > mg/2$	(ii)	Cube will not exhibit motion
(r)	$F > mg$	(iii)	Cube will begin to rotate and slip at A
(s)	$F = mg/4$	(iv)	Normal reaction effectively at $a/3$ from A, no motion.

(a) (p) → (ii)
(b) (q) → (iii)
(c) (r) → (i)
(d) (s) → (iv)

Comprehension Type

A homogeneous block of mass m, width b and height h is resting on a rough horizontal force. A horizontal force F is applied to it, which makes it to move with a constant velocity. The coefficient of friction between block and surface is μ.



12. Find the greatest height at which force F may be applied to slide the block without tipping over.

(a) $\frac{b}{2\mu}$ (b) $\frac{2b}{\mu}$ (c) $\frac{b}{\mu}$ (d) $\frac{2\sqrt{2}b}{\mu}$

13. F is applied at $h/2$. The distance x is the horizontal distance between a point on the bottom face of the block at which resultant of friction and normal force act and CG of the block. Find x?

(a) $\frac{\mu h}{2}$ (b) $\frac{\mu h}{6}$ (c) $\frac{\mu h}{4}$ (d) $\frac{\mu h}{\mu}$

14. Find the maximum height at which F acts so that sliding and tipping are equally likely to occur.

(a) $\frac{b}{\mu}$ (b) $\frac{b}{2\mu}$ (c) $\frac{b}{4\mu}$ (d) $\frac{2b}{\mu}$

Answers Key

Single Correct Answer Type

5. (a) **6.** (a) **7.** (d)

Multiple Correct Answers Type

8. (a, b, c, d) **9.** (b, c) **10.** (a, d)

Comprehension Type

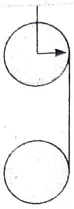
12. (a) **13.** (a) **14.** (b)

DPP 2.4

Torque and Torque Equation

Single Correct Answer Type

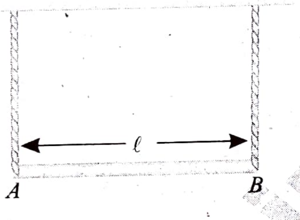
1. Two identical discs of mass m and radius r are arranged as shown in the figure. If α is the angular acceleration of the lower disc and a_{cm} is acceleration of centre of mass of the lower disc, then relation between a_{cm}, α and r is:



(a) $a_{cm} = \dfrac{\alpha}{r}$ (b) $a_{cm} = 2\alpha r$

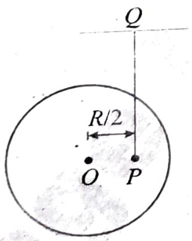
(c) $a_{cm} = \alpha r$ (d) none of these

2. A uniform thin rod of mass 'm' and length L is held horizontally by two vertical strings attached to the two ends. One of the string is cut. Find the angular acceleration soon after it is cut:



(a) $\dfrac{g}{2L}$ (b) $\dfrac{g}{L}$ (c) $\dfrac{3g}{2L}$ (d) $\dfrac{2g}{L}$

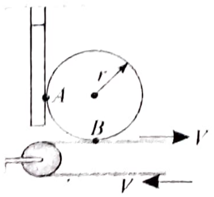
3. A uniform disc of mass M and radius R is released from the shown position. PQ is a string, OP is a horizontal line, O is the centre of the disc and distance OP is $R/2$. Then tension in the string just after the disc is released will be:



(a) $\dfrac{Mg}{2}$ (b) $\dfrac{Mg}{3}$

(c) $\dfrac{2Mg}{3}$ (d) none of these

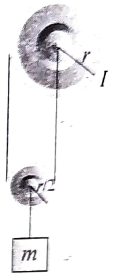
4. A solid cylinder of radius r and mass m is placed with no initial velocity on a moving belt 'B'. It is placed against a rough wall 'A', which restrict the sliding of the cylinder on the belt as shown in the figure. Assuming that the coefficient of friction at A and B is μ (<1), the angular acceleration α of the cylinder will be



(a) $\dfrac{g}{r}\left(\dfrac{\mu}{1+\mu}\right)$ (b) $\dfrac{2g}{r}\left(\dfrac{\mu}{1+\mu}\right)$

(c) $\dfrac{g}{2r}\left(\dfrac{\mu}{1+\mu}\right)$ (d) $\dfrac{g}{r}\left(\dfrac{\mu}{2+\mu}\right)$

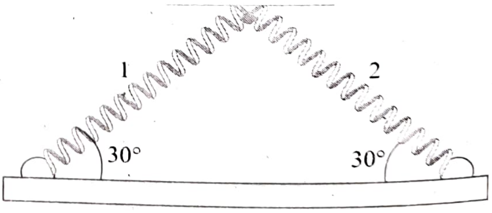
5. A pulley of radius 'r' can rotate about a horizontal axis and its moment of inertia about its axis is I. A light string fixed to the edge of the pulley is wound round it several times, then hangs vertically, passes under a light pulley of radius $r/2$ and then rises vertically. Its other end being attached to the centre of the larger pulley. A particle of mass m is attached to the light pulley. The acceleration of the particle is



(a) $\dfrac{mr^2g}{mr+2I}$ downward (b) $\dfrac{mr^2g}{mr+4I}$ upward

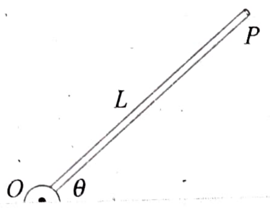
(c) $\dfrac{mr^2g}{mr+4I}$ downward (d) $\dfrac{mr^2g}{mr+2I}$ upward

6. A uniform rod AB of mass m is suspended in equilibrium from two similar springs as shown. If spring 2 breaks. then the angular acceleration of bar at that instant will be ________.



(a) $\dfrac{2g}{l}$ (b) $\dfrac{2g}{3l}$ (c) $\dfrac{3g}{l}$ (d) $\dfrac{g}{3l}$

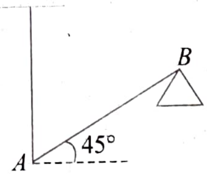
7. A uniform pole of length L and mass M is pivoted on the ground with a frictionless hinge O. The pole is free to rotate without friction about an horizontal axis passing through O and normal to plane of the page. The pole makes an angle with the horizontal. The pole is released from rest in the position shown, then linear acceleration of the free end (P) of the pole just after its release would be:



(a) $\frac{2}{3}g\cos\theta$ (b) $\frac{2}{3}g$

(c) g (d) $\frac{3}{2}g\cos\theta$

8. One end of a thin bar AB of mass m and length l is hanging from a massless string. The other end is held at an angle of 45° with horizontal. Find the tension in the string immediately after release of the bar



(a) $\frac{2}{5}mg$ (b) $\frac{3}{5}mg$ (c) $\frac{4}{5}mg$ (d) $\frac{2\sqrt{2}}{5}mg$

9. A uniform rod of length L (in between the supports) and mass m is placed on two supports A and B. The rod breaks suddenly at length $L/10$ from the support B. Find the reaction at support A immediately after the rod breaks.

(a) $\frac{9}{40}mg$ (b) $\frac{19}{40}mg$ (c) $\frac{mg}{2}$ (d) $\frac{9}{20}mg$

10. A rigid body of radius R, either hollow or solid, lies on a smooth horizontal surface. The body is pulled by a horizontal force acting tangentially from the highest point. The distance travelled by the body in the time in which it makes one full rotation is the same that it will make in one full rotation during pure rolling. The rigid body will be

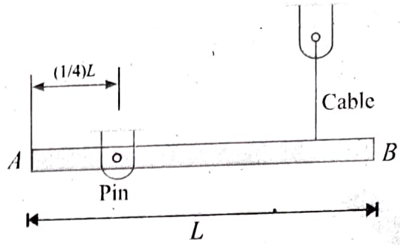
(a) solid sphere (b) hollow sphere

(c) circular disc (d) hollow cylinder

Comprehension Type

For Q. 11 and 12

A uniform beam of length L and mass 'm' is supported as shown. If the cable suddenly breaks, determine, immediately after the release,



11. the acceleration of end B is

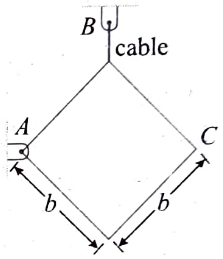
(a) $\frac{9g}{7}\downarrow$ (b) $\frac{11g}{7}\downarrow$ (c) $\frac{9g}{7}\uparrow$ (d) $\frac{11g}{7}\uparrow$

12. the reaction at the pin support is

(a) $\frac{4mg}{7}\downarrow$ (b) $\frac{4mg}{7}\uparrow$ (c) $\frac{5mg}{7}\uparrow$ (d) $\frac{5mg}{7}\downarrow$

For Q. 13 to 15

A uniform square plate of mass m is supported as shown. If the cable suddenly breaks, determine:



13. the angular acceleration of the plate is

(a) $\frac{3g}{2\sqrt{2}b}$ in counter clockwise sense

(b) $\frac{3g}{2\sqrt{2}b}$ in clockwise sense

(c) $\frac{3g}{\sqrt{2}b}$ in clockwise sense

(d) $\frac{3g}{\sqrt{2}b}$ in counter clockwise sense

14. the acceleration of corner C is

(a) $\frac{3}{2}g\downarrow$ (b) $\frac{3}{2}g\uparrow$ (c) $\frac{2}{3}g\uparrow$ (d) $\frac{2}{3}g\downarrow$

15. the reaction at A is

(a) $\frac{Mg}{4}\downarrow$ (b) $\frac{Mg}{3}\uparrow$ (c) $\frac{Mg}{3}\downarrow$ (d) $\frac{Mg}{4}\uparrow$

Answers Key

Single Correct Answer Type

1. (b) **2.** (c) **3.** (c) **4.** (b) **5.** (c)
6. (c) **7.** (d) **8.** (a) **9.** (a) **10.** (d)

Comprehension Type

11. (a) **12.** (b) **13.** (b) **14.** (a) **15.** (d)

CHAPTER

3

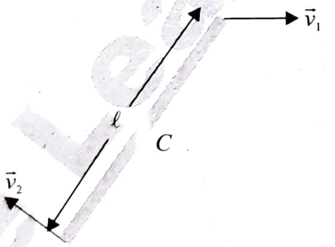
Rigid Body Dynamics II

DPP 3.1

Work and Energy in Case of Rotation

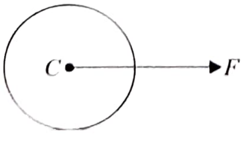
Subjective Type

1. A rod of mass m and length l is moving in such a way that the velocities of end points of a rod are given as $\vec{v}_1$ and $\vec{v}_2$ as shown in the figure. How to calculate the kinetic energy of the rod.?

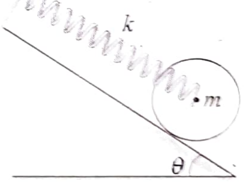


2. A rod of mass m and length l pivoted at P when its angular speed of rotation is $\omega = \sqrt{\frac{g}{l}}$. Find its (i) total kinetic energy (ii) rotational kinetic energy (iii) translational kinetic energy

3. A uniform body rolls on a horizontal surface when pulled by a constant horizontal force F acting at the centre of the body. Assuming no relative sliding between the body and surface, find the work done by friction and applied force F, if the centre C of the rolling body moves through a distance x.

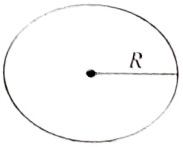


4. A uniform sphere of mass m connected with a light spring of stiffness k at its centre is kept stationary on a slant surface of angle of inclination θ. If the sphere is released from rest when the spring is undeformed, it rolls perfectly down the inclined plane. Derive an expression for velocity of CM of the sphere as a function of elongation x of the spring, using the principle of conservation of energy.



Single Correct Answer Type

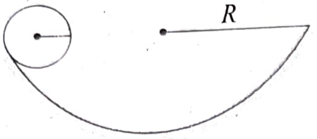
5. What is the ratio of total kinetic energy and translation kinetic energy of rolling body of radius R and radius of gyration k?



(a) $\frac{K_{\text{total}}}{K_{\text{trans}}}=\left(1+\frac{R^2}{k^2}\right)$ (b) $\frac{K_{\text{total}}}{K_{\text{trans}}}=\left(1+\frac{k^2}{R^2}\right)$

(c) $\frac{K_{\text{total}}}{K_{\text{trans}}}=\frac{k^2}{R^2}$ (d) $\frac{K_{\text{total}}}{K_{\text{trans}}}=\frac{R^2}{k^2}$

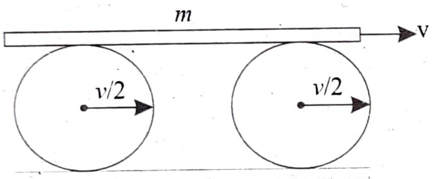
6. A solid sphere of mass m and radius r is released from rest from the given position. If it rolls without sliding on the circular track of radius R, its speed when it reaches its lowest position will be



(a) $\sqrt{\frac{8}{7}g(R-r)}$ (b) $\sqrt{\frac{10}{7}g(R-r)}$

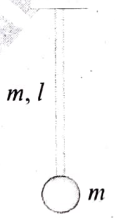
(c) $\sqrt{\frac{10}{9}g(R-r)}$ (d) $\sqrt{\frac{5}{7}g(R-r)}$

7. A plate of mass m is placed on a solid and hollow spheres each of mass m. If the speed of the plate is v, assuming pure rolling of the spheres with all contacting surfaces, the kinetic energy of the system (spheres + plate) will be



(a) $\frac{43}{50}mv^2$ (b) $\frac{33}{50}mv^2$ (c) $\frac{43}{60}mv^2$ (d) $\frac{53}{60}mv^2$

8. A particle is attached to the lower end of a uniform rod which is hinged at its other end as shown in the figure. The minimum speed given to the particle so that the rod performs circular motion in a vertical plane will be: [length of the rod is l, consider masses of both rod and particle to be the same]



(a) $\sqrt{5gl}$ (b) $\sqrt{4gl}$

(c) $\sqrt{4.5gl}$ (d) none of these

Comprehension Type

For Q. 9 to 12

A frictionless hinge supports a bar of mass m and length L in a vertical position. The hinge is a sort of a pivot which can offer no resistance to the bar against an applied moment. However, reaction is what it offers. When the bar comes down to the horizontal position, answer the following questions.

9. Find the angular velocity of the bar at the horizontal position.

(a) $(gL)^{1/2}$ (b) $(2g/L)^{1/2}$

(c) $(3g/L)^{1/2}$ (d) $(4g/L)^{1/2}$

10. Find the velocity of centre of mass at the horizontal position.

(a) $(gL/2)^{1/2}$ (b) $(gL/4)^{1/2}$

(c) $\frac{1}{2}(3gL)^{1/2}$ (d) none of these

11. Find the centripetal force of the centre of mass:

(a) $mg/2$ (b) mg (c) $3mg/2$ (d) $2mg$

12. Find the vertical reaction at hinge in horizontal position.

(a) $mg/2$ (b) $mg/3$ (c) $3mg/2$ (d) $mg/4$

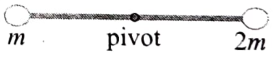
13. Find the reaction at support.

(a) $mg\sqrt{\frac{37}{16}}$ (b) $mg\sqrt{\frac{37}{8}}$

(c) $mg\sqrt{\frac{35}{8}}$ (d) $mg\sqrt{\frac{36}{16}}$

For Q. 14 and 15

A rod of negligible mass and length l is pivoted at its centre. A particle of mass m is fixed to its left end and another particle of mass $2m$ is fixed to the right end. If the system is released from rest. The system rotates about pivot in vertical plane and the becomes vertical.



14. The speed v of the two masses at that instant is

(a) $\sqrt{gl/3}$ (b) $\sqrt{gl/4}$ (c) $\sqrt{2gl/3}$ (d) $\sqrt{3gl/2}$

15. The angular speed ω of the system at that instant is

(a) $\sqrt{g/3l}$ (b) $\sqrt{4g/3l}$ (c) $\sqrt{2g/3l}$ (d) $\sqrt{3g/2l}$

Answers Key

Subjective Type

1. $K=\frac{1}{2}mv_c^2+\frac{1}{2}I_c\omega^2$
2. (i) $\frac{7mgl}{96}$ (ii) $\frac{mgl}{24}$ (iii) $\frac{1}{32}mgl$
3. $W=Fx$
4. $v=\sqrt{\frac{10}{7}gx\sin\theta-\frac{5k}{7m}x^2}$

Single Correct Answer Type

5. (b) 6. (b) 7. (d) 8. (c)

Comprehension Type

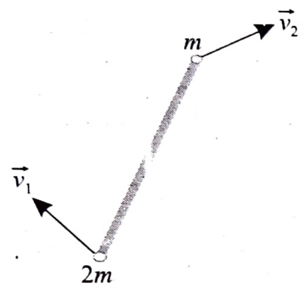
9. (c) 10. (c) 11. (c) 12. (d) 13. (a)
14. (a) 15. (b)

DPP 3.2

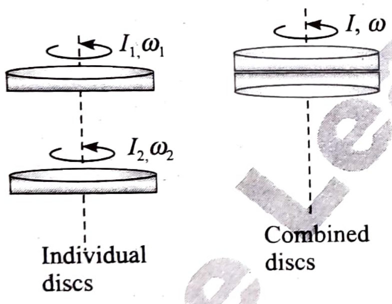
Angular Momentum and Law of Conservation of Angular Momentum

Subjective Type

1. Two particles of masses $2m$ and m interconnected by a uniform rigid rod of mass m move with velocities v_1 and v_2 respectively. Find the momentum of the system (m + rod + $2m$).



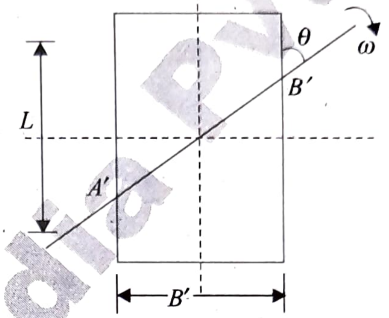
2. Two discs of moments of inertia I_1 and I_2 about their respective axes (normal to the disc and passing through the centre), and rotating with angular speed ω_1 and ω_2 are brought into contact face to face with their axes of rotation coincident.



(a) Does the law of conservation of angular momentum apply to the situation? Why?
(b) Find the angular speed of the two disc system.
(c) Calculate the loss in kinetic energy of the system in the process.
(d) Which force is responsible for this loss?

Single Correct Answer Type

3. A rectangular plate of length L and width B and mass M rotates with angular velocity ω about an axis in x-y plane. The axis of rotation passes through centre of mass and cuts the length of plate at an acute angle θ. Find the angular momentum about z-axis.



(a) $\dfrac{M(L^2+B^2)}{12}\omega$ (b) $\dfrac{M(L^2+B^2)}{6}\omega$

(c) zero (d) $\dfrac{3}{4}M(L^2+B^2)\omega$

4. In the previous problem, find total angular momentum of the plate about centre of mass:

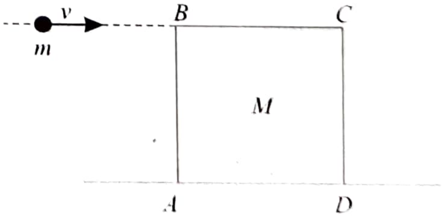
(a) $\dfrac{M\omega}{12}(L^2 \sin\theta\hat{i} + B^2 \cos\theta\hat{j})$

(b) $\dfrac{M\omega}{12}(B^2 \cos\theta\hat{i} + L^2 \sin\theta\hat{j})$

(c) $\dfrac{M\omega}{12}(L^2 \sin^2\theta\hat{i} + B^2 \cos^2\theta\hat{j})$

(d) $\dfrac{M\omega}{12}(B^2 \cos^2\theta\hat{i} + L^2 \sin^2\theta\hat{j})$

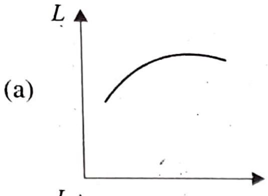
5. A solid cube $ABCD$ of side a and mass M is placed on a rough horizontal surface. A bullet of mass m and speed V is shot at the top of the cube so that cube rotates about point D. The bullet sticks to the cube, $m << M$. Find the angular velocity of the cube.



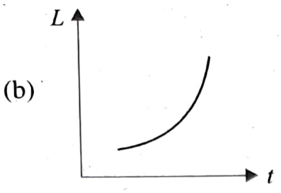
(a) $\dfrac{6mV}{5Ma}$ (b) $\dfrac{3MV}{2ma}$ (c) $\dfrac{2MV}{3ma}$ (d) $\dfrac{2mV}{3Ma}$

6. A ring of mass m and radius R is rolling down a rough inclined plane of angle θ with horizontal. Plot the angular momentum of the ring about the point of contact of ring and the plane as a function of time:

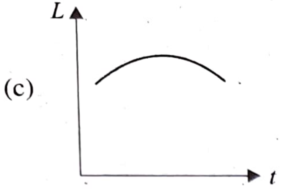
(a)



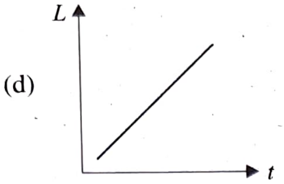
(b)



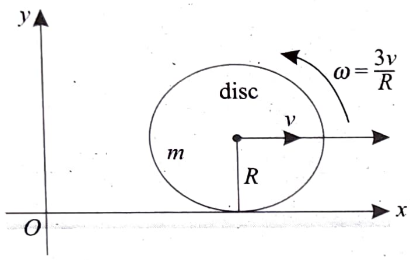
(c)



(d)



7. The angular momentum of the disc which spins with $\vec{w} = \frac{3v}{R}\hat{k}$ and its CM moves with a velocity $\vec{v} = v\hat{i}$ about O will be



(a) $\frac{3mvR}{2}\hat{k}$ (b) $\frac{mvR}{2}\hat{k}$ (c) $-\frac{3mvR}{2}\hat{k}$ (d) $-\frac{mvR}{2}\hat{k}$

8. A merry-go-round, made of a ring-like platform of radius R and mass M, is revolving with angular speed ω. A person of mass M is standing on it. At one instant, the person jumps off the round, radially away from the centre of the round (as seen from the round). The speed of the round of afterwards is

(a) 2ω (b) ω (c) $\frac{\omega}{2}$ (d) 0

9. A particle is moving along a line $y = x + a$ with a constant velocity v. Find the angular momentum of the particle about the origin.

(a) mva (b) $mva\sqrt{2}$ (c) $\frac{mva}{\sqrt{2}}$ (d) $\frac{mvy}{x\sqrt{2}}$

10. Two men of equal masses stand at opposite ends of the diameter of a turntable disc of a certain mass, moving with constant angular velocity. The two men make their way to the middle of the turntable at equal rates.
In doing so

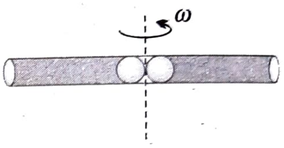
(a) kinetic energy of rotation has increased while angular momentum remains the same.
(b) kinetic energy of rotation has decreased while angular momentum remains same.
(c) kinetic energy of rotation has decreased but angular momentum has increased.
(d) both kinetic energy of rotation and angular momentum have decreased.

Multiple Correct Answers Type

11. Choose the correct alternatives

(a) For a general rotational motion, angular momentum L and angular velocity ω need not be parallel.
(b) For a rotational motion about a fixed axis, angular momentum L and angular velocity ω are always parallel.
(c) For a general translational motion, momentum p and velocity v are always parallel.
(d) For a general translational motion, acceleration a and velocity v are always parallel.

12. A smooth tube of certain mass is rotated in gravity free space and released. The two balls shown in the figure move towards ends of the tube. For the whole system which of the following quantity are conserved.



(a) Angular momentum (b) Linear momentum
(c) Kinetic energy (d) Angular speed

Comprehension Type

Two discs A and B are mounted coaxially on a vertical axle. The discs have moment of inertia I and $2I$ respectively about the common axis. Disc A is imparted an initial angular velocity 2ω using the entire potential energy of a spring compressed by a distance x_1. Disc B is imparted an angular velocity ω by a spring having the same spring constant and compressed by a distance x_2. Both the discs rotate in clockwise direction.

13. Find the ratio (x_1/x_2):

(a) 2 (b) 1/2 (c) $\sqrt{2}$ (d) $1/\sqrt{2}$

14. When disc B is brought in contact with disc A, they acquire a common angular velocity in time t. The average frictional torque on one disc by the other during this period is:

(a) $\frac{2I\omega}{3t}$ (b) $\frac{9I\omega}{2t}$ (c) $\frac{9I\omega}{4t}$ (d) $\frac{3I\omega}{2t}$

15. The loss of kinetic energy during the above process is:

(a) $\frac{I\omega^2}{3t}$ (b) $\frac{I\omega^2}{3}$ (c) $\frac{I\omega^2}{4}$ (d) $\frac{I\omega^2}{6}$

Answers Key

Subjective Type

1. $\vec{P} = 2.5\, m\vec{v}_1 + 1.5\, m\vec{v}_2$

Single Correct Answer Type

3. (a) **4.** (a) **5.** (a) **6.** (d) **7.** (b)
8. (a) **9.** (c) **10.** (a)

Multiple Correct Answers Type

11. (a, c) **12.** (a, b, c)

Comprehension Type

13. (c) **14.** (a) **15.** (b)

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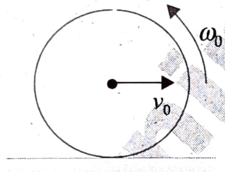
DPP 3.3

Rotation and Translation Combined

Subjective Type

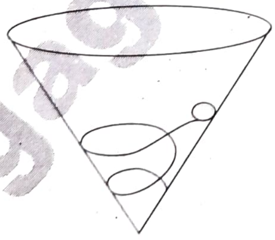
1. A disc of radius R is rotating with an angular ω_0 about a horizontal axis. It is placed on a horizontal table. The coefficient of kinetic friction is μ_K.
   (a) What was the velocity of its centre of mass before being brought in contact with the table?
   (b) What happens to the linear velocity of a point on its rim when placed in contact with the table?
   (c) What happens to the linear speed of the centre of mass when disc is placed in contact with the table?
   (d) Which force is responsible for the effects in (b) and (c)?
   (e) What condition should be satisfied for rolling to begin?
   (f) Calculate the time taken for the rolling to begin.

2. A uniform sphere of radius R is projected on a horizontal surface with a velocity v_0 and simultaneously given a spin ω_0. In consequence, the sphere experiences a combined motion. Due to the friction between the sphere and horizontal surface, both translational and rotational motion will stop simultaneously. Then, what must be the magnitude and direction of initial spin ω_0?



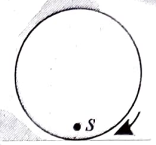
Single Correct Answer Type

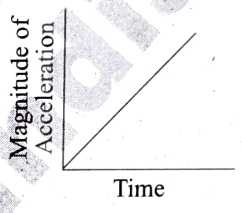
3. A ball is rolling without slipping in a spiral path down the inner surface of a hollow fixed cone whose axis is vertical. The work done by the inner surface of the cone on the ball is

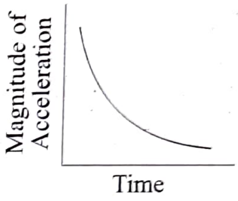


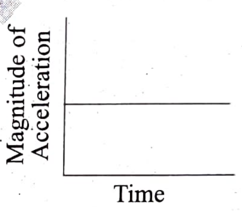
(a) positive
(b) zero
(c) negative
(d) Impossible to determine

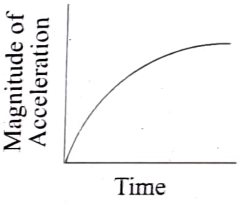
4. As shown in the figure, S is a point on a uniform disc rolling with uniform angular velocity on a fixed rough horizontal surface. The only forces acting on the disc are its weight and contact forces exerted by horizontal surface. Which graph best represents the magnitude of the acceleration of point S as a function of time?



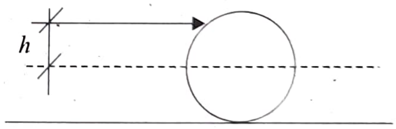
(a)


(b)


(c)


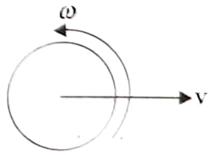
(d)


5. A disc of mass m and radius r is placed on a rough horizontal surface. A cue of mass m hits the disc at a height $r/2$ from the axis passing through centre and parallel to the surface, as shown. The cue stops and falls down after the impact. The disc starts its motion as:



(a) pure rolling
(b) rolling with forward slipping
(c) rolling with backward slipping
(d) pure slipping.

6. A cylinder moves with linear velocity V to the right and angular velocity ω in the anticlockwise direction. The cylinder was initially at rest. The cylinder does not perform pure rolling and stops after some time. Find the radius of the cylinder.



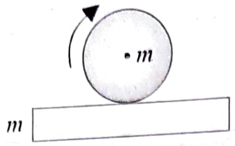
(a) $\dfrac{2V}{3\omega}$ (b) $\dfrac{2V}{\omega}$ (c) $\dfrac{V}{2\omega}$ (d) $\dfrac{3V}{4\omega}$

7. A solid sphere is set into rotation at an angular velocity and it is then placed on a rough horizontal surface. The ratio of distances covered by rotational and translational motions

up to the start of the pure rolling is (Assume uniformly accelerated motion up to start of pure rolling):

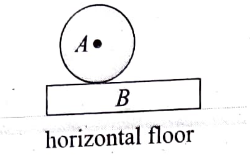
(a) 5/2 (b) 7/2 (c) 7/4 (d) 9/2

8. A sphere of mass 'm' is given some angular velocity about a horizontal axis through its centre and gently placed on a plank of mass 'm'. The coefficient of friction between the two is μ. The plank rests on a smooth horizontal surface. The initial acceleration of the centre of sphere relative to the plank will be:



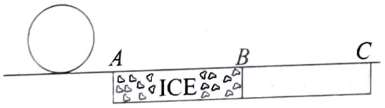
(a) zero (b) μg (c) $(7/5)\mu g$ (d) $2\mu g$

9. A cylinder A rolls without slipping on a plank B. The velocities of center of the cylinder and that of the plank are 4 m/s and 2 m/s respectively in the same direction, with respect to the ground. The angular velocity of the cylinder if its radius is 1 m is:



(a) 2 rad/sec (b) 4 rad/sec
(c) 6 rad/sec (d) 1 rad/sec

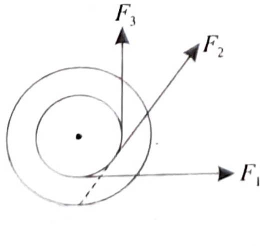
10. A rigid body undergoing uniform pure rolling encounters horizontal tracks AB and BC as shown AB is a smooth layer of ice and BC is a rough surface with $\mu = 1$. Both AB and BC are rigid tracks. Which of the following statements are correct?



(1) the body will slow down over BC
(2) the body will start slipping on AB
(3) the body remains in pure rolling over the whole stretch AC
(4) the angular velocity of the body remains constant over the whole stretch AC.

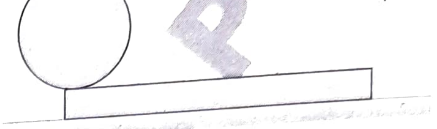
(a) 1 and 2 (b) 1 and 3
(c) 2 and 4 (d) 3 and 4

11. A spool is resting on a horizontal rough table. Forces F_1, F_2 and F_3 are applied separately as shown. F_1, F_2, F_3 all are applied tangentially to the inner circle. F_1 is horizontal, F_3 is vertical and F_2 is passing through the point of contact of spool and table. The correct statement is [Assuming that there is no sliding]



(a) when F_3 is applied the centre of mass will move to the right.
(b) when F_2 is applied the centre of mass will move to the left.
(c) when F_1 is applied the centre of mass will move to the right.
(d) when F_2 is applied the centre of mass will move to the right.

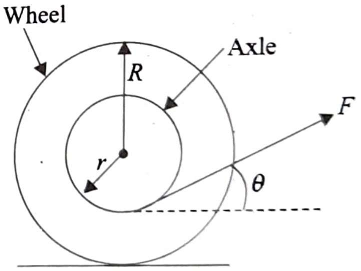
12. A cylinder of mass m is placed on the edge of a plank of the same mass and length $4\mu g t^2$ placed on the smooth horizontal surface, where μ is the coefficient of friction between cylinder and plank and t is the time at which pure rolling starts. The cylinder is given an impulse at $t = 0$ which imparts it a velocity V_0 (m/s). The time in which pure rolling starts will be



(a) $V_0/2\mu g$ (b) $V_0/4\mu g$
(c) $V_0/2\sqrt{2}\mu g$ (d) $V_0/4\sqrt{2}\mu g$

Comprehension Type

A wheel of radius R, mass m with an axle of radius r is placed on a horizontal surface. Its moment of inertia is $I = mR^2$. Unwinding a rope from its axle, a force F is applied to pull it along a horizontal surface. The friction is sufficient enough for its pure rolling. ($\angle\theta = 0°$)



13. Find the linear acceleration of the wheel.

(a) $\dfrac{F[(I/m) - Rr]}{[(I/m) + r^2]}$ (b) $\dfrac{2F[(I/m) - Rr]}{[(I/m) + r^2]}$

(c) $\dfrac{F[(2I/m) - \sqrt{2}Rr]}{[(I/m) + r^2]}$ (d) $\dfrac{F[(I\sqrt{2}/m) - Rr]}{[(I/m) + r^2]}$

14. Find the condition for which frictional force acts in backward direction.

(a) $(I/m) > Rr$ (b) $(2I/m) > Rr$

(c) $\left(\dfrac{I\sqrt{2}}{m}\right) > Rr$ (d) $\left(\dfrac{I}{m\sqrt{2}}\right) > Rr$

15. Find the condition for which frictional force acts in forward direction

(a) $(I/m) < Rr$ (b) $(2I/m) > Rr$

(c) $\left(\dfrac{I\sqrt{2}}{m}\right) < Rr$ (d) $\left(\dfrac{I}{m\sqrt{2}}\right) < Rr$

Answers Key

Single Correct Answer Type

3. (b) **4.** (c) **5.** (a) **6.** (b) **7.** (d)
8. (d) **9.** (a) **10.** (d) **11.** (c) **12.** (b)

Comprehension Type

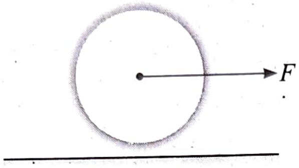
13. (a) **14.** (a) **15.** (a)

DPP 3.4

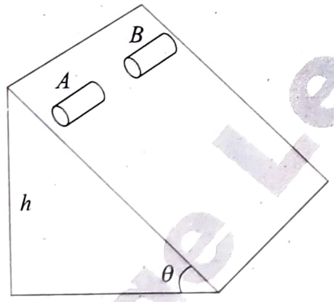
Rolling

Subjective Type

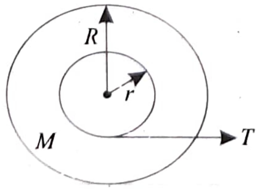
1. A uniform disc of radius R is resting on a table on its rim. The coefficient of friction between disc and table is μ (see figure). Now, the disc is pulled with a force F as shown in the figure. What is the maximum value of F for which the disc rolls without slipping?



2. A 2 kg uniform cylinder is placed on a plank of mass 4 kg which in turn rests on a smooth horizontal plane. A constant horizontal force of 20 N is applied on the plank. If no slipping occurs between cylinder and plank obtain the acceleration of the cylinder and the plank.
3. Two cylinders A and B are released on a fixed rough inclined plane of angle with the horizontal from height 'h'. A is a hollow cylinder and 'B' is a solid cylinder. Both perform pure rolling. Find the distance between the two cylinders when one of them reaches the bottom. Assume that the axis of both cylinders is parallel to the edge CD always.



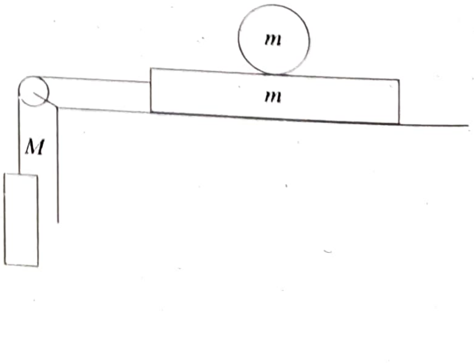
4. A spool of mass $M = 3$ kg and radius $R = 20$ cm has an axle of radius $r = 10$ cm around which a string is wrapped. The moment of inertia about an axis perpendicular to the plane of the spool and passing through the centre is $\frac{MR^2}{2}$. Coefficient of friction between the surface and the spool is 0.4. Find maximum value of the tension T (in N) that can be applied so that the spool rolls without slipping.



[Take $g = 10$ m/s^2]

Single Correct Answer Type

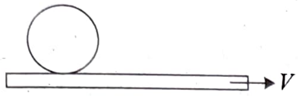
5. A wheel starts rolling with an angular velocity and initial linear velocity up an inclined rough plane of an angle θ with horizontal and coefficient of friction μ. The linear deceleration of given by
   (a) $g(3\mu\cos\theta - \sin\theta)$ (b) $g(3\mu\cos\theta - 2\sin\theta)$
   (c) $g(2\mu\cos\theta - 3\sin\theta)$ (d) $g(3\mu\cos\theta - (1/2)\sin\theta)$
6. A wheel of radius r starts rolling with an angular velocity ω and initial linear velocity V_0 up and inclined smooth plane. The wheel will stop going up in time:
   (a) $\frac{V_0}{g\sin\theta}$ (b) $\frac{r\omega}{g\sin\theta}$ (c) $\frac{V_0 - r\omega}{g\sin\theta}$ (d) $\frac{r\omega - V_0}{g\sin\theta}$
7. A solid sphere of radius R starts rotating on rough horizontal surface with translational velocity V_0 and initial angular velocity $\omega_0 = \frac{2V_0}{3R}$. The sphere starts pure rolling after some time t. Find the angle by which sphere rotates up to the instant at which pure rolling starts, if V is the translational velocity at pure rolling. Assume uniformly accelerated motion upto start of pure rolling:
   (a) $\frac{33}{38}\frac{Vt}{R}$ (b) $\frac{37}{38}\frac{Vt}{R}$ (c) $\frac{31}{38}\frac{Vt}{R}$ (d) $\frac{29}{37}\frac{Vt}{R}$
8. In the previous problem, if S is the distance covered by the sphere in rotational motion up to the instant at which pure rolling starts, find the velocity (translational) of the sphere during the pure rolling.
   (a) $\frac{33}{38}\frac{S}{t}$ (b) $\frac{37}{38}\frac{S}{t}$ (c) $\frac{31}{38}\frac{S}{t}$ (d) $\frac{38}{33}\frac{S}{t}$
9. A plate of mass m is placed on a frictionless surface. The plate is connected to block of mass M through a rope over a massless pulley. A cylinder of mass m is placed on the plate which rolls without slipping. Find the frictional force acting on the cylinder.



(a) $\dfrac{(M+m)g}{6}$ (b) $\dfrac{mg}{6}$

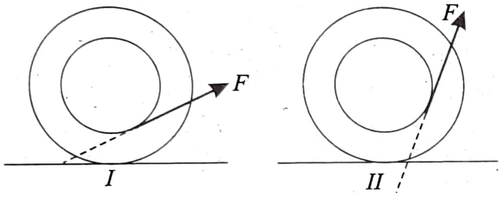
(c) $\dfrac{Mmg}{3(M+2m)}$ (d) $\dfrac{2(M+m)g}{3}$

10. A solid sphere of mass m and radius r is gently placed on a conveyer belt moving with constant velocity V. If the coefficient of friction between the belt and sphere is $\dfrac{2}{7}$, the distance travelled by the centre of the sphere before it starts pure rolling is



(a) $\dfrac{V^2}{7g}$ (b) $\dfrac{2V^2}{49g}$ (c) $\dfrac{2V^2}{5g}$ (d) $\dfrac{2V^2}{7g}$

11. The string of a step rolling wheel is pulled by applying force F with different lines of action in two situations as shown. The wheel starts rolling without slipping due to application of the force.



(a) The wheel rolls to the right in situation I and to the left in situation II.
(b) The wheel rolls to the left in situation I and to the right in situation II.
(c) The wheel rolls to the right in both situations.
(d) The wheel rolls to the left in both situations.

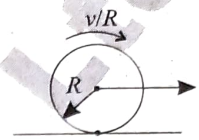
12. A solid sphere, a hollow sphere and a disc, all having same mass and radius, are placed at the top of an incline and released. The friction coefficients between the objects and the incline are the same and not sufficient to allow pure rolling. Least time will be taken in reaching the bottom by

(a) the solid sphere (b) the hollow sphere
(c) the disc (d) all will take the same time

13. In the previous question, the smallest kinetic energy at the bottom of the incline will be achieved by

(a) the solid sphere
(b) the hollow sphere
(c) the disc
(d) all will achieve the same kinetic energy

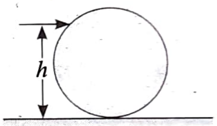
14. A disc is performing pure rolling on a smooth stationary surface with constant angular velocity as shown in the figure. At any instant, for the lower most point of the disc



(a) velocity is v, acceleration is zero
(b) velocity is zero, acceleration is zero
(c) velocity is v, acceleration is $\dfrac{v^2}{R}$
(d) velocity is zero, acceleration is $\dfrac{v^2}{R}$

Matching Column Type

15. A uniform sphere of mass m and radius R is placed on a rough horizontal surface (see figure). The sphere is struck horizontally at a height h from the floor. Match the following.



Column I		Column II	
(p)	$h = R/2$	(i)	Sphere rolls without slipping with a constant velocity and no loss of energy.
(q)	$h = R$	(ii)	Sphere spins clockwise, loses energy by friction
(r)	$h = 3R/2$	(iii)	Sphere spins anti-clockwise, loses energy by friction.
(s)	$h = 7R/5$	(iv)	Sphere has only a translational motion, looses energy by friction.

Answers Key

Subjective Type

1. $3\mu Mg$

2. $a_1 = \dfrac{10}{7}\,\text{m/s}^2,\ a_2 = \dfrac{30}{7}\,\text{m/s}^2$

3. $d = \dfrac{3h}{g\sin\theta}$

4. 18 N

Single Correct Answer Type

5. (a)	**6.** (a)	**7.** (a)	**8.** (d)	**9.** (c)
10. (a)	**11.** (a)	**12.** (d)	**13.** (b)	**14.** (d)

Matching Column Type

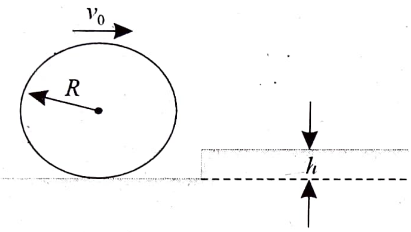
15. (p) → (iii); (q) → (iv) (q) → (iii) (s) → (i)

DPP 3.5

Angular Impulse and Collision of Rigid Bodies

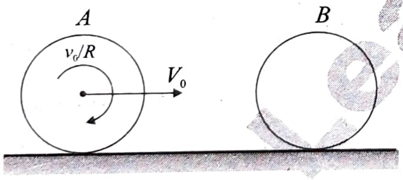
Subjective Type

1. A uniform solid sphere of radius R is rolling without sliding on a horizontal surface with a velocity v_0. It collides with an obstacle of height h ($< R$) inelastically. Find the angular speed of the sphere just after the collision.



Single Correct Answer Type

2. A hollow smooth uniform sphere A of mass 'm' rolls without sliding on a smooth horizontal surface. It collides elastically and head-on with another stationary smooth solid sphere B of the same mass m and same radius. The ratio of kinetic energy of 'B' to that of 'A' just after the collision is:

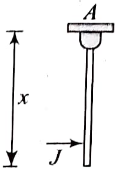


(a) 5 : 2 (b) 1 : 1 (c) 2 : 3 (d) 3 : 2

3. A uniform rod AB of mass m and length l is at rest on a smooth horizontal surface. An impulse J is applied to the end B perpendicular to the rod in horizontal direction. Speed of particle P at a distance $\frac{l}{6}$ from the center towards A of the rod after time $t = \frac{\pi m l}{12\,J}$ is

(a) $2\frac{J}{m}$ (b) $\frac{J}{\sqrt{2}\,m}$ (c) $\frac{J}{m}$ (d) $\sqrt{2}\frac{J}{m}$

4. A uniform rod of length l is pivoted at point A. It is struck by a horizontal force which delivers an impulse J at a distance x from point A as shown in the figure, impulse delivered by pivot is zero if x is equal to



(a) $\frac{l}{2}$ (b) $\frac{l}{3}$ (c) $\frac{2l}{3}$ (d) $\frac{3l}{4}$

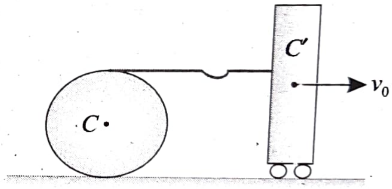
5. A homogenous rod of length $l = \eta x$ and mass M is lying on a smooth horizontal floor. A bullet of mass m hits the rod at a distance x from the middle of the rod at a velocity v_0 perpendicular to the rod and comes to rest after collision. If the velocity of the farther end of the rod just after the impact is in the opposite direction of v_0, then

(a) $\eta > 3$ (b) $\eta < 3$ (c) $\eta > 6$ (d) $\eta < 6$

Comprehension Type

For Q. 6 to 8

A smooth uniform disc of mass m and radius R is connected with a heavy cart C' by an inextensible string. When the cart is pushed with a velocity v_0,



6. The linear impulse exerted on the disc will be

(a) mv_0 (b) $\frac{mv_0}{3}$ (c) $\frac{2mv_0}{3}$ (d) $\frac{mv_0}{2}$

7. Velocity of the disc after impulse will be

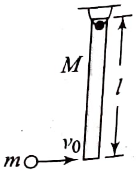
(a) v_0 (b) $\frac{2v_0}{3}$ (c) $\frac{v_0}{2}$ (d) $\frac{v_0}{3}$

8. Angular velocity of the disc after impulse will be

(a) $\frac{2v_0}{3R}$ (b) $\frac{v_0}{3R}$ (c) $\frac{v_0}{R}$ (d) $\frac{v_0}{2R}$

For Q. 9 to 11

A particle of mass m moving horizontally with a velocity v_0 collides and sticks to the bottom of the smoothly pivoted hanging rod of mass M (= 3 m) and length l.



9. The angular speed of the rod just after the collision is:

(a) $\frac{v_0}{2l}$ (b) $\frac{v_0}{l}$ (c) $\frac{2v_0}{l}$ (d) $\frac{3v_0}{2l}$

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10. The fraction loss of KE of the system (rod + particle) during collision is:

(a) $\frac{1}{2}$ (b) $\frac{3}{4}$

(c) $\frac{2}{3}$ (d) None of these

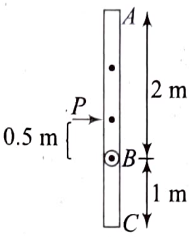
11. The maximum height raised by the CM of the rod is

(a) $\frac{3v_0^2}{32g}$ (b) $\frac{5v_0^2}{32g}$

(c) $\frac{v_0^2}{5g}$ (d) None of these

For Q. 12 to 15

Two uniform rods AB and BC of masses 1 kg and 2 kg respectively having lengths 2 m and 1 m respectively are joined to each other at B. They can rotate freely about B without any friction. The assembly is kept on a smooth horizontal surface as shown in the figure. A horizontal impulse P = 10 Ns is applied on the rod AB at a distance 0.5 m from point B perpendicular to the rod.



12. The angular speed of rod BC just after the application of impulse is

(a) 12.5 rad/s (b) 2.5 rad/s

(c) 6.25 rad/s (d) 15 rad/s

13. Velocity of centre of rod AB just after the application of impulse is

(a) $\frac{25}{12}$ m/s (b) $\frac{35}{6}$ m/s

(c) $\frac{25}{2}$ m/s (d) 6 m/s

14. Impulse applied by the rod BC on the rod AB during application of impulse P is

(a) 25 N-s (b) 10 N-s (c) $\frac{25}{6}$ N-s (d) 12.5 N-s

15. Angular momentum of rod BC about centre of rod BC just after application of impulse is

(a) $\frac{25}{12}$ kg-m^2/s (b) $\frac{35}{6}$ kg-m^2/s

(c) $\frac{25}{2}$ kg-m^2/s (d) 6 kg-m^2/s

Answers Key

Subjective Type

1. $\omega = \left(1 - \frac{5h}{7R}\right)\frac{v_0}{R}$

Single Correct Answer Type

2. (d) **3.** (d) **4.** (c) **5.** (d)

Comprehension Type

6. (b) **7.** (d) **8.** (a) **9.** (a) **10.** (b)
11. (d) **12.** (a) **13.** (b) **14.** (c) **15.** (a)

CHAPTER

4

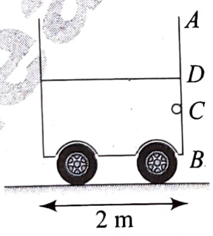
Fluid Mechanics

DPP 4.1

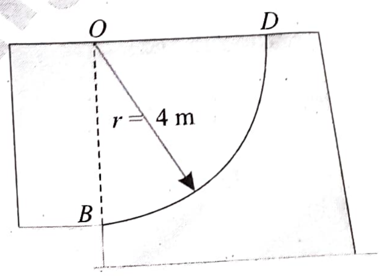
Pressure and Density

Subjective Type

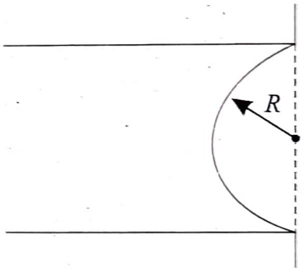
1. A cubical container with side 2 m has a small hole with a cap at point C as shown. The water level is up to point D. (BC = 0.5 m and BD = 1.5 m). If container is given an acceleration of 8 m/s^2 and the hole is opened simultaneously, find the amount of water that will spill out of the container (in litres).



2. The figure shows a quarter cylindrical dam surface retaining water. The density of water is 1000 kg/m^3. The length of the dam normal to paper is b = 30 m. Determine the horizontal and vertical components of the force due to water on the dam.

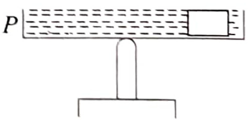


3. A hemispherical gate of radius R is just submerged in water of density ρ as shown in figure. Find the thrust on the gate due to water in
   (a) horizontal direction
   (b) vertical direction
   Also calculate
   (c) total hydrostatic force acting on gate
   (d) angle of orientation of total hydrostatic force acting on the hemispherical gate.
   Do not count atmospheric pressure.

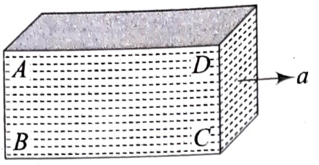


Single Correct Answer Type

4. An open pan P filled with water (density ρ_w) is placed on a vertical rod, maintaining equilibrium. A block of density ρ is placed on one side of the pan as shown. Water depth is more than height of the block.



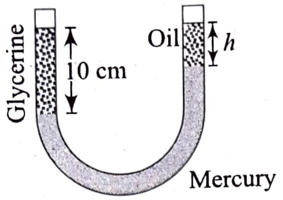
   (a) Equilibrium will be maintained only if $\rho < \rho_w$.
   (b) Equilibrium will be maintained only if $\rho \leq \rho_w$.
   (c) Equilibrium will be maintained for all relations between ρ and ρ_w.
   (d) Equilibrium will not be maintained in all cases.



5. A closed rectangular tank is completely filled with water and is accelerated horizontally with an acceleration a towards right. Pressure is (i) maximum at, and (ii) minimum at

(a) (i) B (ii) D (b) (i) C (ii) D

(c) (i) B (ii) C (d) (i) B (ii) A



6. A vertical U-tube of uniform inner cross section contains mercury in both sides of its arms. A glycerin (density = 1.3 g/cm^3) column of length 10 cm is introduced into one of its arms. Oil of density 0.8 gm/cm^3 is poured into the other arm until the upper surfaces of the oil and glycerin are in the same horizontal level. Find the length of the oil column. Density of mercury = 13.6 g/cm^3.

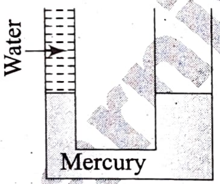
(a) 10.4 cm (b) 8.2 cm

(c) 7.2 cm (d) 9.6 cm

7. A triangular lamina of area A and height h is immersed in a liquid of density ρ in a vertical plane with its base on the surface of the liquid. The thrust on the lamina is

(a) $\frac{1}{2}A\rho gh$ (b) $\frac{1}{3}A\rho gh$

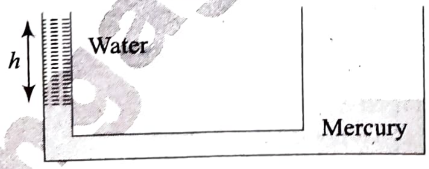
(c) $\frac{1}{6}A\rho gh$ (d) $\frac{2}{3}A\rho gh$



8. A U-tube in which the cross-sectional area of the limb on the left is one-quarter, the limb on the right contains mercury (density 13.6 g/cm^3). The level of mercury in the narrow limb is at a distance of 36 cm from the upper end of the tube. What will be the rise in the level of mercury in the right limb if the left limb is filled to the top with water?

(a) 1.2 cm (b) 2.35 cm (c) 0.56 cm (d) 0.8 cm

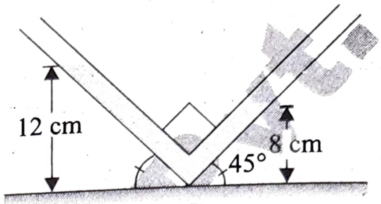
9. Two communicating vessels contain mercury. The diameter of one vessel is n times larger than the diameter of the other. A column of water of height h is poured into the left vessel. The mercury level will rise in the right-hand vessel (s = relative density of mercury and ρ = density of water) by



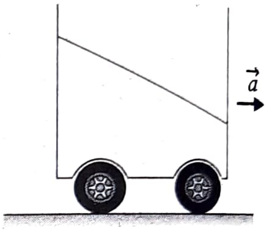
(a) $\frac{n^2h}{(n+1)^2s}$ (b) $\frac{h}{(n^2+1)s}$

(c) $\frac{h}{(n+1)^2s}$ (d) $\frac{h}{n^2s}$

10. An L-shaped glass tube is kept inside a bus that is moving with constant acceleration. During the motion, the level of the liquid in the left arm is at 12 cm whereas in the right arm, it is at 8 cm when the orientation of the tube is as shown. Assuming that the diameter of the tube is much smaller than levels of the liquid and neglecting effect of surface tension, acceleration of the bus will be (g = 10 m/s^2)



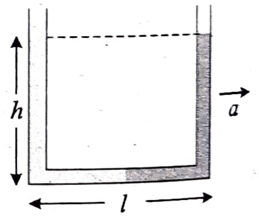
(a) 1 m/s^2 (b) 2 m/s^2 (c) 4 m/s^2 (d) 5 m/s^2



11. An open water tanker moving on a horizontal straight road has a cubical block of cork floating over its surface. If the tanker has an acceleration of a as shown, the acceleration of the cork w.r.t. container is

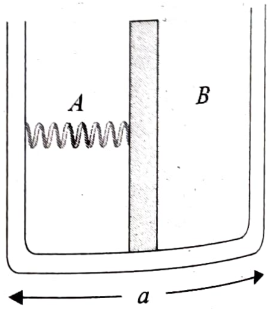
(a) Zero (b) $\frac{a^2}{g}$

(c) $\frac{a}{y}\sqrt{g^2-a^2}$ (d) a



12. A U-tube of base length 'l' filled with same volume of two liquids of densities ρ and 2ρ is moving with an acceleration 'a' on the horizontal plane. If the height difference between the two surfaces (open to atmosphere) becomes zero, then the height h is given by

(a) $\frac{a}{2g}l$ (b) $\frac{3a}{2g}l$ (c) $\frac{a}{g}l$ (d) $\frac{2a}{3g}l$



13. A broad vessel with a square base of edge a = 10 cm is separated into two halves A and B by a smooth vertical piston. A spring of spring constant k = 1500 N/m is filled across the compartment A and the compartment B is filled with water to a height 20 cm. Find the compression in the spring.

(a) 1.3 cm (b) 2.1 cm (c) 3.9 cm (d) 0.07 cm

14. A rectangular gate 3 m × 1 m stands vertical with water on one side of it hinged at the middle. The force F required to the applied at the bottom to keep the gate in equilibrium is

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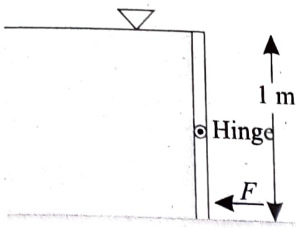


(a) 3.0×10^4 N-m
(b) 1.0×10^4 N-m
(c) 0.5×10^4 N-m
(d) 0.75×10^4 N-m

Multiple Correct Answers Type

15. Pressure is a scalar quantity because
  (a) it is the ratio of force to area and both force and area are vectors
  (b) it is the ratio of the magnitude of the force to area
  (c) it is the ratio of the component of the force normal to the area
  (d) it does not depend on the size of the area chosen

Answers Key

Subjective Type

1. 1200 litres
2. 2400 kN, 1200π kN
3. (a) $\rho g \pi R^3$ (right) (b) $\frac{2}{3}\rho g \pi R^3$ (up)
(c) $\frac{\sqrt{13}}{3}\rho g \pi R^3$ (d) $\tan^{-1}\frac{3}{2}$ with vertical

Single Correct Answer Type

4. (b) **5.** (a) **6.** (d) **7.** (b) **8.** (c)
9. (b) **10.** (b) **11.** (a) **12.** (b) **13.** (a)
14. (c)

Multiple Correct Answers Type

15. (b, c)

DPP 4.2

Buoyancy and Floatation

Single Correct Answer Type

1. A glass beaker of mass 400 g floats in water with the open end just touching the surface of water and half of the beaker filled with water. The inner volume of the beaker is 500 cm^3. What is the density of the material of the beaker?
(a) 1.52 g cm^{-3} (b) 2.67 g cm^{-3}
(c) 3.01 g cm^{-3} (d) 3.87 g cm^{-3}

2. Two bodies are in equilibrium when suspended in water from the arms of a balance. The mass of one body is 36 g and its density is 9 g/cm^3. If the mass of the other is 48 g, its density in g/cm^3 is
(a) $\frac{4}{3}$ (b) $\frac{3}{2}$ (c) 3 (d) 5

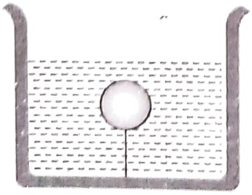
3. A body of density d_1 is counterpoised by Mg of weights of density d_2 in air of density d. Then the true mass of the body is
(a) M (b) $M\left(1-\frac{d}{d_2}\right)$
(c) $M\left(1-\frac{d}{d_1}\right)$ (d) $\frac{M(1-d/d_2)}{(1-d/d_1)}$

4. A log of wood of mass 120 kg floats in water. The weight that can be put on the raft to make it just sink should be (density of wood = 600 kg/m^3)
(a) 80 kg (b) 50 kg (c) 60 kg (d) 30 kg

5. A hemispherical bowl just floats without sinking in a liquid of density 1.2×10^3 kg/m^3. If outer diameter and the density of the bowl are 1 m and 2×10^4 kg/m^3, respectively, then the inner diameter of the bowl will be
(a) 0.94 m (b) 0.97 m (c) 0.98 m (d) 0.99 m

6. A concrete sphere of radius R has a cavity of radius r which is packed with sawdust. The specific gravities of concrete and sawdust are, respectively, 2.4 and 0.3 for this sphere to float with its entire volume submerged under water. The ratio of mass of concrete to mass of sawdust will be
(a) 8 (b) 4 (c) 3 (d) Zero

7. A solid sphere of density $\eta(> 1)$ times lighter than water is suspended in a water tank by a string tied to its base as shown in the figure. If the mass of the sphere is m then the tension in the string is given by

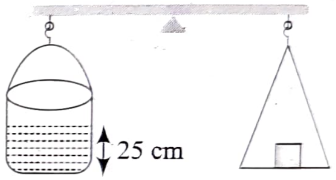


(a) $\left(\frac{\eta-1}{\eta}\right)mg$ (b) ηmg
(c) $\frac{mg}{\eta-1}$ (d) $(\eta-1)mg$

8. A hollow sphere of volume V is floating on water surface with half immersed in it. What should be the minimum volume of water poured inside the sphere so that the sphere now sinks into the water?
(a) $V/2$ (b) $V/3$ (c) $V/4$ (d) V

9. A ball whose density is 0.4×10^3 kg/m^3 falls into water from a height of 9 cm. To what depth does the ball sink?
(a) 9 cm (b) 6 cm (c) 4.5 cm (d) 2.25 cm

10. A cylinder containing water up to a height of 25 cm has a hole of cross-section $\frac{1}{4}$ cm^2 in its bottom. It is counterpoised in a balance. What is the initial change in the balancing weight when water begins to flow out?



(a) Increase of 12.5 gm-wt
(b) Increase of 6.25 gm-wt
(c) Decrease of 12.5 gm-wt
(d) Decrease of 6.25 gm-wt

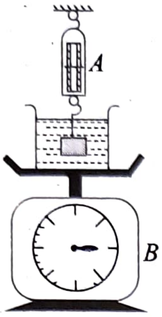
11. The thickness of the ice layer on the surface of lake is 20 m. A hole is made in the ice layer. What is the minimum length of the rope required to take a bucket full of water out? Take density of ice = 0.9×10^3 kg/m^3.
(a) 2 m (b) 5 m (c) 9 m (d) 18 m

12. A uniform rod of density ρ is placed in a wide tank containing a liquid of density $\rho_0(\rho_0 > \rho)$. The depth of liquid in the tank is half the length of the rod. The rod is in equilibrium, with its lower end resting on the bottom of the tank. In this position, the rod makes an angle θ with the horizontal
(a) $\sin\theta = \frac{1}{2}\sqrt{\rho_0/\rho}$ (b) $\sin\theta = \frac{1}{2}\cdot\frac{\rho_0}{\rho}$
(c) $\sin\theta = \sqrt{\rho/\rho_0}$ (d) $\sin\theta = \rho_0/\rho$

Multiple Correct Answers Type

13. The spring balance A reads 2 kg with a block suspended from it. A balance B reads 5 kg when a beaker with liquid

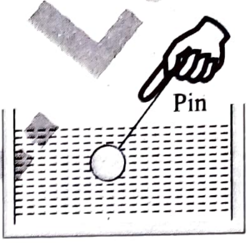
is put on the pan of the balance. The two balances are now so arranged that the hanging mass is inside the liquid in the beaker as shown in figure. In this situation



(a) balance A will read more than 2 kg
(b) balance B will read more than 5 kg
(c) balance A will read less than 2 kg and B will read more than 5 kg
(d) balances A and B will read 2 kg and 5 kg, respectively.

14. A body totally immersed in water is raised in the water by a height h. The density of the body is d and the density of water is d_0 while the volume of the body is V and $d > d_0$. Which of the given statements will be true?
(a) The net work done on raising the body is $Vdgh$.
(b) The increase in the potential energy of the body is $Vgh(d - d_0)$.
(c) The potential energy of water is not changed by raising the body.
(d) The work done on the body by the gravitational force is equal and opposite to the work done by the hydrostatic force so that net work done is zero.

Fill in the Blanks Type



15. A vessel with water is placed on a weighing pan and it reads 600 g. Now a ball of 40 g and density 0.80 g/cc is sunk into the water with a pin of negligible volume as shown in the figure, keeping it sunk. The reading of weighing pan will be..........

16. A hollow sphere of relative density 2 floats completely immersed on the surface of water. If the volume of the sphere be V, then the volume of the cavity will be..........

17. A cube of each side L floats in a liquid of density 3 times the density of cube. The length of the cube will be outside the liquid..............

18. A wooden ball of density ρ is immersed in a liquid of density σ to a depth H and then released. The height h above the surface to which the ball rises will be..........

19. Two solids A and B float in water. It is observed that A floats with $\frac{1}{2}$ of its body immersed in water and B floats with $\frac{1}{4}$ of its volume above the water level. The ratio of the density of A to that of B is........

Answers Key

Single Correct Answer Type

1. (b) **2.** (c) **3.** (d) **4.** (a) **5.** (c)
6. (b) **7.** (d) **8.** (a) **9.** (b) **10.** (c)
11. (a) **12.** (a)

Multiple Correct Answers Type

13. (b, c) **14.** (b, c)

Fill in the Blanks Type

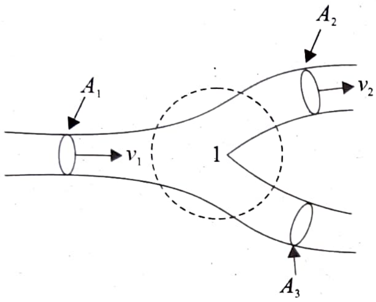
15. 650 g **16.** $V/2$ **17.** $2L/3$ **18.** $\left(\frac{\sigma - \rho}{\rho}\right)H$
19. $\frac{2}{3}$

DPP 4.3

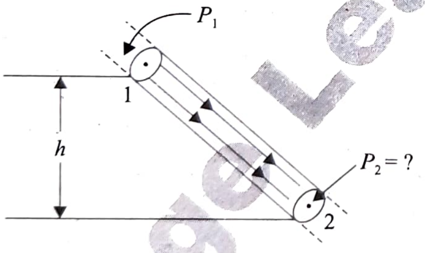
Application of Bernoulli's Theorem

Subjective Type

1. An ideal liquid in a tube of uniform cross-sectional area $A_1 = 0.01\ \text{m}^2$ flows with a speed $v_1 = 2$ m/s. At junction 1, the streamlines of the liquid divide into two parts, part of the liquid flux (liquid) moves in a tube of uniform cross-sectional area $A_2 = 0.02\ \text{m}^2$ with a velocity $v_2 = 3$ m/s. Find the velocity of liquid in the other branch of uniform cross-sectional area $A_3 = 0.03\ \text{m}^2$.



2. A liquid moves in a smooth tube of uniform cross-section. Find the pressure P_2 at point 2 of the tube if the pressure at point 1 of the extended tube is P_1 and the vertical distance between points 1 and 2 is h.

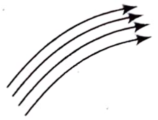


3. Describe the "principle of aerodynamic lift". Derive the expression for aerodynamics lift on any object of arbitrary shape and size.

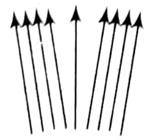
Single Correct Answer Type

4. Which of the following diagrams does not represent a streamline flow?

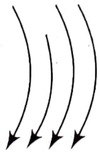
(a)



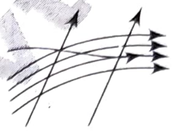
(b)



(c)

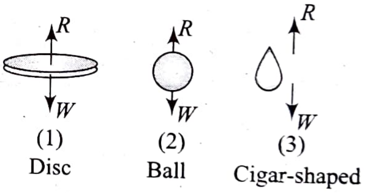


(d)



5. Along a streamline,
   (a) the velocity of a fluid particle remains constant
   (b) the velocity of all fluid particles crossing a given position is constant
   (c) the velocity of all fluid particles at a given instant is constant
   (d) the speed of a fluid particle remains constant.

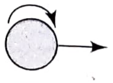
6. When a body falls in air, the resistance of air depends to a great extent on the shape of the body, three different shapes are given. Identify the combination of air resistances which truly represents the physical situation. (The cross sectional areas are the same).



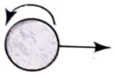
(a) $1 < 2 < 3$
(b) $2 < 3 < 1$
(c) $3 < 2 < 1$
(d) $3 < 1 < 2$

7. To get the maximum flight, a ball must be thrown as

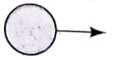
(a)



(b)

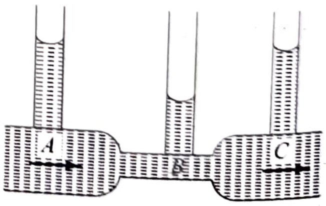


(c)



(d) Any of (a), (b) and (c)

8. In the following figure is shown the flow of liquid through a horizontal pipe. Three tubes A, B and C are connected to the pipe. The radii of the tubes A, B and C at the junction are respectively 2 cm, 1 cm and 2 cm. It can be said that the

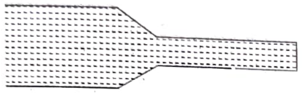


(a) height of the liquid in the tube A is maximum
(b) height of the liquid in the tubes A and B is the same
(c) height of the liquid in all the three tubes is the same
(d) height of the liquid in the tubes A and C is the same

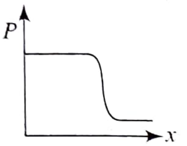
9. A manometer connected to a closed tap reads 3.5×10^5 N/m^2. When the valve is opened, the reading of manometer falls to 3.0×10^5 N/m^2, then velocity of flow of water is

(a) 100 m/s (b) 10 m/s (c) 1 m/s (d) $10\sqrt{10}$ m/s

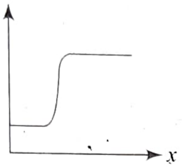
10. Water flows through a frictionless duct with a cross-section varying as shown in the figure. Pressure p at points along the axis is represented by



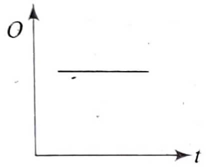
(a)



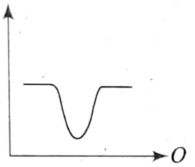
(b)



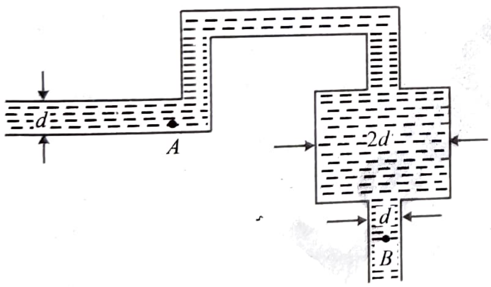
(c)



(d)

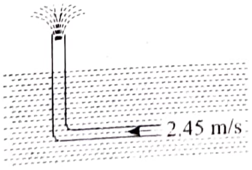


11. An ideal fluid is flowing through the given tubes which is placed on a horizontal surface. If the liquid has velocities V_A and V_B, and pressures P_A and P_B at points A and B respectively, then the correct relation is (A and B are at the same height from ground level, the figure shown is as if the system is seen from the top):



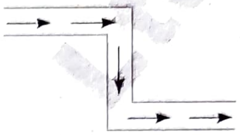
(a) $V_A > V_B$, $P_A < P_B$ (b) $V_A < V_B$, $P_A > P_B$
(c) $V_A = V_B$, $P_A = P_B$ (d) $V_A > V_B$, $P_A = P_B$

12. An L-shaped tube with a small orifice is held in a water stream as shown in the figure. The upper end of the tube is 10.6 cm above the surface of water. What will be the height of the jet of water coming from the orifice? Velocity of water stream is 2.45 m/s.



(a) Zero (b) 20.0 cm
(c) 10.6 cm (d) 40.0 cm

13. The tube shown in the figure is of uniform cross-section. Liquid flows through it at a constant speed in the direction shown by arrows. Then the liquid exerts on the tube is:



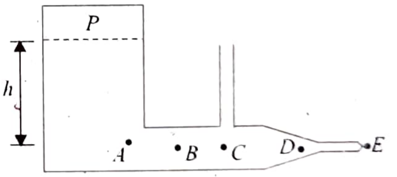
(a) a net force to the right
(b) a net force to the left
(c) a clockwise torque
(d) an anticlockwise torque

14. Water from a tap emerges vertically downwards with an initial velocity V_0. Assume pressure is constant throughout the stream of water and the flow is steady, find the distance from the tap at which cross-sectional area of stream is half of the cross-sectional area of stream at the tap:

(a) $V_0^2/2g$ (b) $3V_0^2/2g$
(c) $2V_0^2/g$ (d) $5V_0^2/2g$

Multiple Correct Answers Type

15. As shown in the figure a liquid of density ρ is standing in a sealed container to a height h. The container contains compressed air at a gauge pressure of p. The horizontal outlet pipe has a cross-sectional area is $A/2$ at E. Find the correct options.



(a) The velocity of liquid at C will be $\left[\frac{(p+\rho gh}{4\rho}\right]^{1/2}$

(b) The velocity of liquid at C will be $\left[\frac{2(p+\rho gh)}{\rho}\right]^{1/2}$

(c) The discharge rate is given by $\frac{A}{2\rho}(p+\rho gh)^{1/2}$

(d) The discharge rate is given by $\frac{A}{2\sqrt{\rho}}(p+\rho gh)^{1/2}$

Answers Key

Subjective Type

1. $\frac{4}{3}$ m/s towards left direction of A_3
2. $P_2 = P_1 + \rho gh$

Single Correct Answer Type

4. (d) 5. (b) 6. (c) 7. (b) 8. (d)

9. (b) 10. (a) 11. (c) 12. (b) 13. (c)
14. (b)

Multiple Correct Answers Type

15. (a, d)

DPP 4.4

Application of Bernoulli's Theorem and Velocity of Efflux

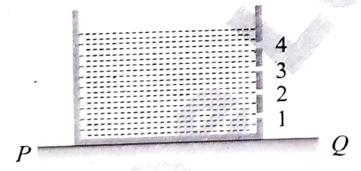
Single Correct Answer Type

1. A large tank is filled with water to a height H. A small hole is made at the base of the tank. It takes T_1 time to decrease the height of water to $\frac{H}{\eta}(\eta > 1)$; and it takes T_2 time to take out the rest of water. If $T_1 = T_2$, then the value of η is
   (a) 2 (b) 3 (c) 4 (d) $2\sqrt{2}$

2. There is a hole in the bottom of tank having water. If total pressure at bottom is 3 atm (1 atm = 10^5 N/m^2), then the velocity of water flowing from hole is
   (a) $\sqrt{400}$ m/s (b) $\sqrt{600}$ m/s
   (c) $\sqrt{60}$ m/s (d) None of these

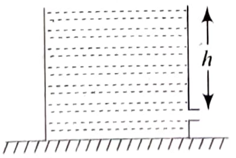
3. A cylindrical tank has a hole of 1 cm^2 in its bottom. If the water is allowed to flow into the tank from a tube above it at the rate of 70 cm^3/sec, then the maximum height up to which water can rise in the tank is
   (a) 2.5 cm (b) 5 cm (c). 10 cm (d) 0.25 cm

4. A cylindrical vessel of 90 cm height is kept filled up to the brim. It has four holes 1, 2, 3 and 4 which are respectively at heights of 20 cm, 30 cm, 45 cm and 50 cm from the horizontal floor PQ. The water falling at the maximum horizontal distance from the vessel comes from



   (a) Hole number 4 (b) Hole number 3
   (c) Hole number 2 (d) Hole number 1

5. In the figure shown, a light container is kept on a horizontal rough surface of coefficient of friction $\mu = \frac{Sh}{V}$. A very small hole of area S is made at depth 'h'. Water of volume 'V' is filled in the container. The friction is not sufficient to keep the container at rest. The acceleration of the container initially is



   (a) $\frac{V}{Sh}g$ (b) g (c) zero (d) $\frac{Sh}{V}g$

6. There is a small hole in the bottom of a fixed container containing a liquid up to height 'h'. The top of the liquid as well as the hole at the bottom are exposed to atmosphere. As the liquid comes out of the hole. (Area of the hole is 'a' and that of the top surface is 'A'):
   (a) the top surface of the liquid accelerates with acceleration = g
   (b) the top surface of the liquid accelerates with acceleration = $g\frac{a^2}{A^2}$
   (c) the top surface of the liquid retards with retardation = $g \cdot \frac{a}{A}$
   (d) the top surface of the liquid retards with retardation = $\frac{ga^2}{A^2}$

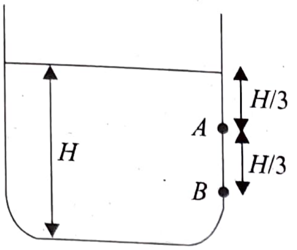
7. A large open tank has two holes in the wall. One is a square hole of side L at a depth y from the top and the other is a circular hole of radius R at a depth $4y$ from the top. When the tank is completely filled with water, the quantities of water flowing out per sec from both the holes are the same. Then, R is equal to:
   (a) $\frac{L}{\sqrt{2\pi}}$ (b) $2\pi L$ (c) L (d) $\frac{L}{2\pi}$

8. A liquid is kept in a cylindrical vessel which is being rotated about a vertical axis through the centre of the circular base. If the radius of the vessel is r and angular velocity of rotation is ω, then the difference in the heights of the liquid at the centre of the vessel and the edge is
   (a) $\frac{r\omega}{2g}$ (b) $\frac{r^2\omega^2}{2g}$ (c) $\sqrt{2gr\omega}$ (d) $\frac{\omega^2}{2gr^2}$

Multiple Correct Answers Type

9. The velocity of efflux of an ideal liquid does not depend on:
   (a) the depth of point below the free surface of liquid
   (b) the area of orifice
   (c) the density of liquid
   (d) the area of cross-section of the vessel

10. The area of two holes A and B are $2a$ and a respectively. The holes are at height (H/3) and ($2H$/3) from surface of water. Find correct option (s):



(a) The velocity of efflux at hole B is 2 times the velocity of efflux at hole A.

(b) The velocity of efflux at hole B is $\sqrt{2}$ time the velocity of efflux at hole A.

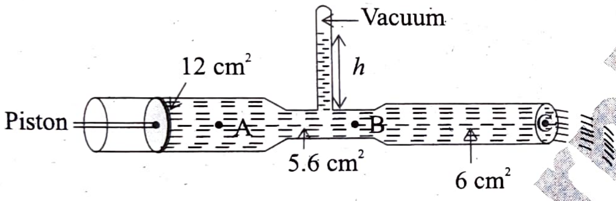
(c) The discharge is the same through both the holes.

(d) The discharge through hole A is $\sqrt{2}$ time the discharge through hole B.

Comprehension Type

For Q. 11 to 13

A glass tube has three different cross sectional areas with the values indicated in the figure. A piston at the left end of the tube exerts pressure so that the mercury within the tube flows from the right end with a speed of 8.0 m/s. Three points within the tube are labeled A, B and C. The atmospheric pressure is 1.01×10^5 N/m^2; and the density of mercury is 1.36×10^4 kg/m^3 (use $g = 10$ m/s^2)



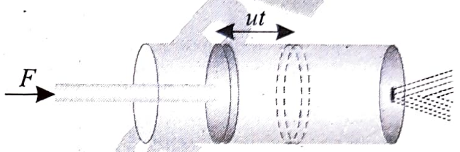
11. At what speed is mercury flowing past the point A?
(a) 2.0 m/s (b) 4.0 m/s (c) 8.0 m/s (d) 12 m/s

12. The pressure at point A is equal to:
(a) 2.02×10^5 Pa (b) 2.25×10^5 Pa
(c) 3.26×10^5 Pa (d) 4.27×10^5 Pa

13. The height h of mercury in the manometer is
(a) 136 mm (b) 169 mm (c) 272 mm (d) 366 mm

For Q. 14 and 15

A syringe, as shown in the figure, contains an ideal fluid of density ρ. The cross-section area of plunger is A and the small orifice at the end of the cylinder has area a.



14. The velocity of outflow of a liquid from the syringe if the plunger moves with a constant velocity under the action of force F is

(a) $\sqrt{\dfrac{2F}{\rho A}}$ (b) $\sqrt{\dfrac{F}{\rho A}}$

(c) $\sqrt{\dfrac{F}{2\rho A}}$ (d) $\sqrt{\dfrac{3F}{\rho A}}$

15. If the volume of fluid is V, the work must you do to empty the cylinder in time t will be

(a) $\dfrac{\rho V^3}{a^2 t^2}$ (b) $\dfrac{\rho V^3}{2a^2 t^2}$ (c) $\dfrac{2\rho V^3}{a^2 t^2}$ (d) $\dfrac{\rho V^3}{3a^2 t^2}$

Answers Key

Single Correct Answer Type

1. (c) **2.** (a) **3.** (a) **4.** (b) **5.** (d)
6. (d) **7.** (a) **8.** (b)

Multiple Correct Answers Type

9. (b, c, d) **10.** (b, d)

Comprehension Type

11. (b) **12.** (d) **13.** (c) **14.** (a) **15.** (b)

CHAPTER

5

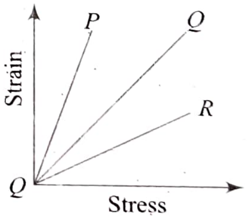
Properties of Matter

DPP 5.1

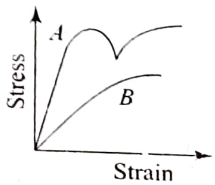
Stress, Strain and Elasticity

Single Correct Answer Type

1. A copper wire and a steel wire of the same diameter and length are connected end to end and a force is applied, which stretches their combined length by 1 cm. The two wires will have
   (a) different stresses and strains
   (b) the same stress and strain
   (c) the same strain but different stresses
   (d) the same stress but different strains
2. There are two wires of the same material and the same length while the diameter of second wire is two times the diameter of first wire, then ratio of extension produced in the wires by applying the same load will be
   (a) 1 : 1 (b) 2 : 1 (c) 1 : 2 (d) 4 : 1
3. A 5 m long aluminium wire ($Y = 7 \times 10^{10}$ N/m^2) of diameter 3 mm supports a 40 kg mass. In order to have the same elongation in a copper wire ($Y = 12 \times 10^{10}$ N/m^2) of the same length under the same weight, the diameter should now be (in mm).
   (a) 1.75 (b) 1.5 (c) 2.9 (d) 5.0
4. Two wires A and B are of the same materials. Their lengths are in the ratio 1 : 2 and diameters are in the ratio 2 : 1 when stretched by force F_A and F_B respectively, they get equal increase in their lengths. Then the ratio F_A/F_B should be
   (a) 1 : 2 (b) 1 : 1 (c) 2 : 1 (d) 8 : 1
5. The strain–stress curves of three wires of different materials are shown in the figure. P, Q and R are the elastic limits of the wires. The figure shows that

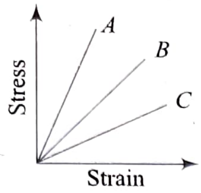


   (a) Elasticity of wire P is maximum
   (b) Elasticity of wire Q is maximum
   (c) Tensile strength of R is maximum
   (d) None of the above is true
6. The diagram shows stress vs. strain curve for the materials A and B. From the curves we infer that



   (a) A is brittle but B is ductile
   (b) A is ductile and B is brittle
   (c) Both A and B are ductile
   (d) Both A and B are brittle

7. The stress–strain curves for brass, steel and rubber are shown in the figure. The lines A, B and C are for



(a) Rubber, brass and steel respectively
(b) Brass, steel and rubber respectively
(c) Steel, brass and rubber respectively
(d) Steel, rubber and brass respectively

8. A steel ring of radius r and cross-section area 'A' is fitted on to a wooden disc of radius $R(R > r)$. If Young's modulus be E, then the force with which the steel ring is expanded is

(a) $AE\dfrac{R}{r}$ (b) $AE\left(\dfrac{R-r}{r}\right)$

(c) $\dfrac{E}{A}\left(\dfrac{R-r}{A}\right)$ (d) $\dfrac{Er}{AR}$

9. A uniform cube is subjected to volume compression. If each side is decreased by 1%, then bulk strain is
(a) 0.01 (b) 0.06
(c) 0.02 (d) 0.03

10. The pressure applied from all directions on a cube is P. How much its temperature should be raised to maintain the original volume? The volume elasticity of the cube is β and the coefficient of volume expansion is α.

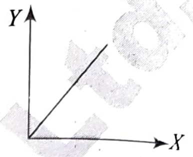
(a) $\dfrac{P}{\alpha\beta}$ (b) $\dfrac{P\alpha}{\beta}$

(c) $\dfrac{P\beta}{\alpha}$ (d) $\dfrac{\alpha\beta}{P}$

11. Mark the wrong statement
(a) Sliding of molecular layer is much easier than compression or expansion
(b) Reciprocal of bulk modulus of elasticity is called compressibility
(c) It is difficult to twist a long rod as compared to small rod
(d) Hollow shaft is much stronger than a solid rod of the same length and the same mass

Multiple Correct Answers Type

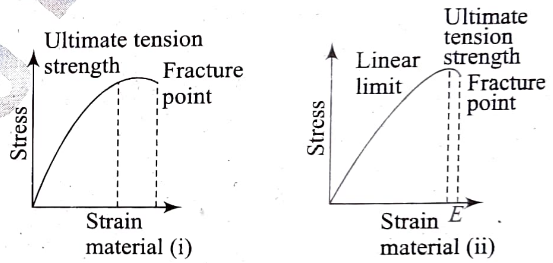
12. A student plots a graph from his readings on the determination of Young's modulus of a metal wire but forgets to write the labels (as shown in the figure). The quantities on X- and Y-axes may be respectively:



(a) weight hung and length increased
(b) stress applied and length increased
(c) stress applied and strain developed
(d) length increased and the weight hung

13. Which of the following statements are correct?
(a) Young's modulus, bulk modulus and shear modulus have the units of pressure
(b) The value of Young's modulus depends on the dimensions of the body
(c) Modulus of elasticity is the smallest value of stress required to produce a permanent distortion in a body
(d) Young's modulus describes the length elasticity of a material.

14. The stress–strain graphs for two materials are shown in figure (assume the same scale)



(a) Material (ii) is more elastic than material (i) and hence material (ii) is more brittle
(b) Material (i) and (ii) have the same elasticity and the same brittleness
(c) Material (ii) is elastic over a larger region of strain as compared to (i)
(d) Material (ii) is more brittle than material (i)

15. A copper and a steel wire of the same diameter are connected end to end. A deforming force F is applied to this composite wire, which causes a total elongation of 1 cm. The two wires will have
(a) the same stress (b) different stress
(c) the same strain (d) different strain

Answers Key

Single Correct Answer Type

1. (d) 2. (d) 3. (c) 4. (d) 5. (d)
6. (b) 7. (c) 8. (b) 9. (d) 10. (a)
11. (c)

Multiple Correct Answers Type

12. (a, b, c, d) 13. (a, d) 14. (c, d) 15. (a, d)

DPP 5.2

Elasticity and Work Done in Stretching a Wire

Single Correct Answer Type

1. If the potential energy of a spring is V on stretching it by 2 cm, then its potential energy when it is stretched by 10 cm will be
(a) $V/25$ (b) $5V$ (c) $V/5$ (d) $25V$

2. Two wires of the same diameter and of the same material have the length l and $2l$. If the force F is applied on each, the ratio of the work done in the two wires will be
(a) 1 : 2 (b) 1 : 4 (c) 2 : 1 (d) 1 : 1

3. A 5 metre long wire is fixed to the ceiling. A weight of 10 kg is hung at the lower end and is 1 metre above the floor. The wire was elongated by 1 mm. The energy stored in the wire due to stretching is
(a) Zero (b) 0.05 J
(c) 100 J (d) 500 J

4. A brass rod of cross-sectional area 1 cm^2 and length 0.2 m is compressed lengthwise by a weight of 5 kg. If Young's modulus of elasticity of brass is 1×10^{11} N/m^2 and $g = 10$ m/sec^2, then the increase in the energy of the rod will be
(a) 10^{-5} J (b) 2.5×10^{-5} J
(c) 5×10^{-5} J (d) 2.5×10^{-4} J

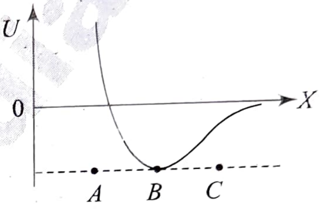
5. If one end of a wire is fixed with a rigid support and the other end is stretched by a force of 10 N, then the increase in length is 0.5 mm. The ratio of the energy of the wire and the work done in displacing it through 1.5 mm by the weight is
(a) $\frac{1}{3}$ (b) $\frac{1}{4}$ (c) $\frac{1}{2}$ (d) 1

6. K is the force constant of a spring. The work done in increasing its extension from l_1 to l_2 will be
(a) $K(l_2 - l_1)$ (b) $\frac{K}{2}(l_2 + l_1)$
(c) $K(l_2^2 - l_1^2)$ (d) $\frac{K}{2}(l_2^2 - l_1^2)$

7. When a 4 kg mass is hung vertically on a light spring that obeys Hooke's law, the spring stretches by 2 cm. The work required to be done by an external agent in stretching this spring by 5 cm will be ($g = 9.8$ metres/sec^2)
(a) 4.900 J (b) 2.450 J
(c) 0.495 J (d) 0.245 J

8. Wires A and B are made from the same material. A has twice the diameter and three times the length of B. If the elastic limits are not reached, when each is stretched by the same tension, the ratio of energy stored in A to that in B is
(a) 2 : 3 (b) 3 : 4 (c) 3 : 2 (d) 6 : 1

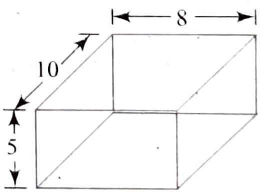
9. The potential energy U between two molecules as a function of the distance X between them has been shown in the figure. The two molecules are



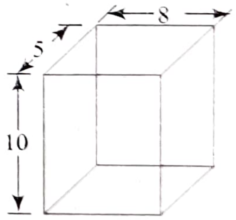
(a) Attracted when x lies between A and B and are repelled when X lies between B and C
(b) Attracted when x lies between B and C and are repelled when X lies between A and B
(c) Attracted when they reach B
(d) Repelled when they reach B

10. A rod of length l and radius r is joined to a rod of length $l/2$ and radius $r/2$ of the same material. The free end of small rod is fixed to a rigid base and the free end of larger rod is given a twist of $\theta°$, the twist angle at the joint will be
(a) $\theta/4$ (b) $\theta/2$ (c) $5\theta/6$ (d) $8\theta/9$

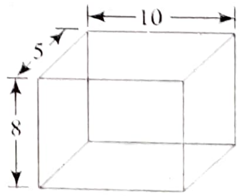
11. A rectangular block of size 10 cm × 8 cm × 5 cm is kept in three different positions P, Q and R in turn as shown in the figure. In each case, the shaded area is rigidly fixed and a definite force F is applied tangentially to the opposite face to deform the block. The displacement of the upper face will be



(P)



(Q)



(R)

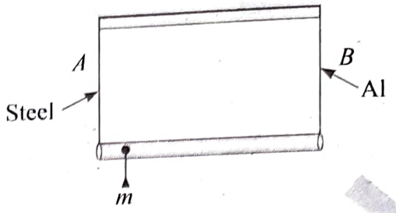
(a) Same in all the three cases
(b) Maximum in P position
(c) Maximum in Q position
(d) Maximum in R position

12. The elongation in a metallic rod hinged at one end and rotating in a horizontal plane becomes four times of the initial value. The angular velocity of rotation becomes
(a) two times the initial value
(b) half of initial value
(c) one-third of initial value
(d) four times the initial value.

Multiple Correct Answers Type

13. When a wire is stretched to double its length:
(a) its radius is halved
(b) strain is unity
(c) stress is equal to Young's modulus
(d) Young's modulus is equal to twice are correct regarding unit volume

14. A rod of length l and negligible mass is suspended at its two ends by two wires of steel (wire A) and aluminium (wire B) of equal lengths (see figure).
The cross-sectional areas of wires A and B are 1.0 mm^2 and 2.0 mm^2, respectively.
($Y_{AL} = 70 \times 10^9$ Nm^{-2} and $Y_{steel} = 200 \times 10^9$ Nm^{-2})



(a) Mass m should be suspended close to wire A to have equal stresses in both the wires
(b) Mass m should be suspended close to B to have equal stresses in both the wires
(c) Mass m should be suspended at the middle of the wires to have equal stresses in both the wires
(d) Mass m should be suspended close to wire A to have equal strain in both wires

15. A composite rod consists of a steel rod of length 25 cm and area $2A$ and a copper rod of length 50 cm and area A. The composite rod is subjected to an axial load F. If the Young's moduli of steel and copper are in the ratio 2 : 1.
(a) the extension produced in copper rod will be more
(b) the extension in copper and steel parts will be in the ratio 1 : 2
(c) the stress applied to copper rod will be more
(d) no extension will be produced in the steel rod

Answers Key

Single Correct Answer Type

1. (d) **2.** (a) **3.** (b) **4.** (b) **5.** (c)
6. (d) **7.** (b) **8.** (b) **9.** (b) **10.** (d)
11. (d) **12.** (a)

Multiple Correct Answers Type

13. (b, c, d) **14.** (b, d) **15.** (b, c)

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DPP 5.3

Surface Tension and Surface Energy

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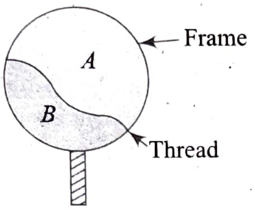
Single Correct Answer Type

1. A thread is tied slightly loose to a wire frame as in the figure and the frame is dipped into a soap solution and taken out. The frame is completely covered with the film. When the portion A is punctured with a pin, the thread



   (a) becomes concave toward A
   (b) becomes convex towards A
   (c) remains in the initial position
   (d) either (a) or (b) depending on the size of A w.r.t. B

2. The maximum force, in addition to the weight required to pull a wire of 5.0 cm long from the surface of water at temperature 20°C is 728 dynes. The surface tension of water is
   (a) 7.28 N/cm
   (b) 7.28 dyne/cm
   (c) 72.8 dyne/cm
   (d) 7.28×10^2 dyne/cm

3. Consider a liquid contained in a vessel. The liquid solid adhesive force is very weak as compared to the cohesive force in the liquid. The shape of the liquid surface near the solid shall be
   (a) horizontal
   (b) almost vertical
   (c) concave
   (d) convex

4. A thin metal disc of radius r floats on water surface and bends the surface downwards along the perimeter making an angle θ with vertical edge of the disc. If the disc displaces a weight of water W and surface tension of water is T, then the weight of metal disc is
   (a) $2\pi rT + W$
   (b) $2\pi rT \cos\theta - W$
   (c) $2\pi rT \cos\theta + W$
   (d) $W - 2\pi rT \cos\theta$

5. Energy needed in breaking a drop of radius R into n drops of radii r is given by
   (a) $4\pi T(nr^2 - R^2)$
   (b) $\frac{4}{3}\pi(r^3 n - R^2)$
   (c) $4\pi T(R^2 - nr^2)$
   (d) $4\pi T(nr^2 + R^2)$

6. The radius of a soap bubble is increased from $\frac{1}{\sqrt{\pi}}$ cm to $\frac{2}{\sqrt{\pi}}$ cm. If the surface tension of water is 30 dynes per cm, then the work done will be
   (a) 180 ergs
   (b) 360 ergs
   (c) 720 ergs
   (d) 960 ergs

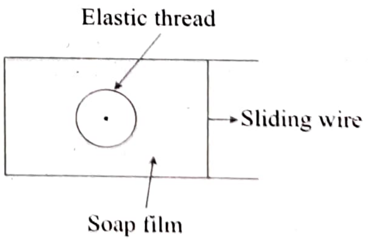
7. One thousand small water drops of equal radii combine to form a big drop. The ratio of final surface energy to the total initial surface energy is
   (a) 1000 : 1 (b) 1 : 1000 (c) 10 : 1 (d) 1 : 10

8. A film of water is formed between two straight parallel wires of length 10 cm each separated by 0.5 cm. If their separation is increased by 1 mm while still maintaining their parallelism, how much work will have to be done (Surface tension of water = 7.2×10^{-2} N/m)
   (a) 7.22×10^{-6} J
   (b) 1.44×10^{-5} J
   (c) 2.88×10^{-5} J
   (d) 5.76×10^{-5} J

9. There is a horizontal film of soap solution. On it a thread is placed in the form of a loop. The film is pierced inside the loop and the thread becomes a circular loop of radius R. If the surface tension of the loop be T, then what will be the tension in the thread
   (a) $\pi R^2/T$ (b) $\pi R^2 T$ (c) $2\pi RT$ (d) $2RT$

10. A large number of water drops each of radius r combine to have a drop of radius R. If the surface tension is T and the mechanical equivalent of heat is J, then the rise in temperature will be
    (a) $\frac{2T}{rJ}$
    (b) $\frac{3T}{RJ}$
    (c) $\frac{3T}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$
    (d) $\frac{2T}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$

11. The figure shows a soap film in which a closed elastic thread is lying. The film inside the thread is pricked. Now the sliding wire is moved out so that the surface area increases. The radius circle of the circle formed by elastic thread will



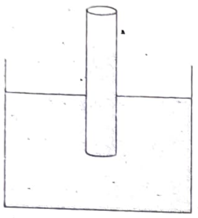
    (a) increase
    (b) decrease
    (c) remains the same
    (d) data insufficient

12. A mosquito with 8 legs stands on water surface and each leg makes depression of radius 'a'. If the surface tension and angle of contact are 'T' and zero respectively, then the weight of mosquito is:

(a) $8T.a$ (b) $16\pi Ta$

(c) $\frac{Ta}{8}$ (d) $\frac{Ta}{16\pi}$

13. A long capillary tube of mass 'π' gm, radius 2 mm and negligible thickness is partially immersed in a liquid of surface tension 0.1 N/m. Take angle of contact zero and neglect buoyant force of liquid. The force required to hold the tube vertically will be ($g = 10$ m/s^2)



(a) 10.4π mN (b) 10.8π mN

(c) 0.8π mN (d) 4.8π mN

Fill in the Blanks Type

14. The dimensions of surface tension are......

15. A square frame of side L is dipped in a liquid. On taking out, a membrane is formed. If the surface tension of the liquid is T, the force acting on the frame will be.....

16. Force necessary to pull a circular plate of 5 cm radius from water surface for which surface tension is 75 dynes/cm is ....

17. A 10 cm long wire is placed horizontally on the surface of water and is gently pulled up with a force of 2×10^{-2} N to keep the wire in equilibrium. The surface tension, in Nm^{-1}, of water is........

18. The force required to separate two glass plates of area 10^{-2} m^2 with a film of water 0.05 mm thick between them is (Surface tension of water is 70×10^{-3} N/m)......

19. A wooden stick 2 m long is floating on the surface of water. The surface tension of water 0.07 N/m. By putting soap solution on one side of the sticks the surface tension is reduced to 0.06 N/m. The net force on the stick will be ......

20. The force required to take away a flat circular plate of radius 2 cm from the surface of water will be (the surface tension of water is 70 dyne/cm).....

21. Two droplets merge with each other and forms a large droplet. In this process ......

22. The surface tension of a liquid is 5 N/m. If a thin film of the area 0.02 m^2 is formed on a loop, then its surface energy will be.......

23. If work W is done in blowing a bubble of radius R from a soap solution, then the work done in blowing a bubble of radius $2R$ from the same solution is.......

24. If two identical mercury drops are combined to form a single drop, then its temperature will........

25. If the surface tension of a liquid is T, the gain in surface energy for an increase in liquid surface by A is........

Answers Key

Single Correct Answer Type

1. (a) **2.** (c) **3.** (d) **4.** (c) **5.** (a)
6. (c) **7.** (d) **8.** (b) **9.** (d) **10.** (c)
11. (c) **12.** (b) **13.** (b)

Fill in the Blanks Type

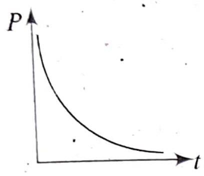
14. $[ML^0T^{-2}]$ **15.** $8\,TL$ **16.** 750π dynes
17. 0.1 **18.** 28 N **19.** 0.02 N
20. 280π dyne **21.** Energy is liberated
22. 2×10^{-1} J **23.** $4W$ **24.** Increase
25. AT

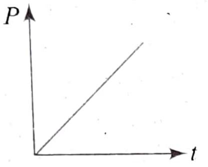
DPP 5.4

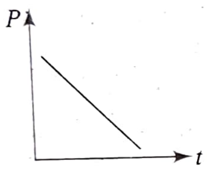
Surface Tension (Pressure Difference and Capillarity)

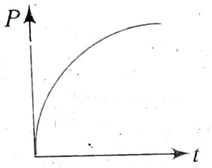
Single Correct Answer Type

1. A soap bubble is blown with the help of a mechanical pump at the mouth of a tube. The pump produces a certain increase per minute in the volume of the bubble, irrespective of its internal pressure. The graph between the pressure inside the soap bubble and time t will be

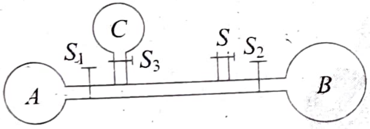
(a)


(b)


(c)


(d)


2. The adjoining diagram shows three soap bubbles A, B and C prepared by blowing the capillary tube fitted with stop cocks, S_1, S_2 and S_3. With stop cock S closed and stop cocks S_1, S_2 and S_3 opened



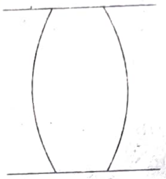
(a) B will start collapsing with volumes of A and C increasing
(b) C will start collapsing with volumes of A and B increasing
(c) C and A both will start collapsing with the volume of B increasing
(d) Volumes of A, B and C will become equal at equilibrium

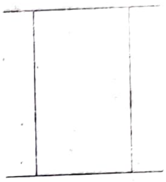
3. Pressure inside two soap bubbles are 1.01 and 1.02 atmospheres. Ratio between their volumes is
(a) 102 : 101 (b) $(102)^3 : (101)^3$
(c) 8 : 1 (d) 2 : 1

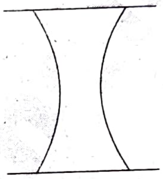
4. If pressure at half the depth of a lake is equal to 2/3 pressure at the bottom of the lake, then what is the depth of the lake
(a) 10 m (b) 20 m (c) 60 m (d) 30 m

5. The pressure inside a small air bubble of radius 0.1 mm situated just below the surface of water will be equal to [Take surface tension of water 70×10^{-3} Nm^{-1} and atmospheric pressure = 1.013×10^5 nm^{-2}]
(a) 2.054×10^3 Pa (b) 1.027×10^3 Pa
(c) 1.027×10^5 Pa (d) 2.054×10^5 Pa

6. If a water drop is kept between two glass plates, then its shape is

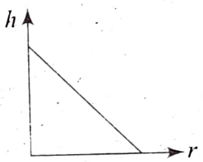
(a)


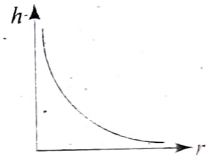
(b)


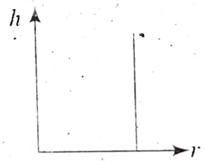
(c)


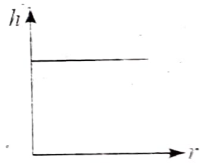
(d) None of these

7. The correct curve between the height or depression h of liquid in a capillary tube and its radius is

(a)


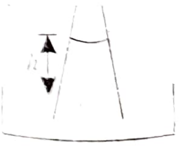
(b)


(c)


(d)


8. Water rises to a height of 16.3 cm in a capillary of height 18 cm above the water level. If the tube is cut at a height of 12 cm,
(a) water will come as a fountain from the capillary tube
(b) water will stay at a height of 12 cm in the capillary tube
(c) the height of the water in the capillary will be 10.3 cm
(d) water will flow down the sides of the capillary tube

9. A capillary of the shape as shown is dipped in a liquid. Contact angle between the liquid and the capillary is 0° and effect of liquid inside the meniscus is to be neglected. T is the surface tension of the liquid, r is the radius of the meniscus, g is the acceleration due to gravity and ρ is the density of the liquid, then height h in equilibrium is:



(a) greater than $\frac{2T}{r\rho g}$ (b) equal to $\frac{2T}{r\rho g}$

(c) less than $\frac{2T}{r\rho g}$

(d) of any value depending upon act

10. Two parallel glass plates are dipped partly in the liquid of density 'd' keeping them vertical. If the distance between the plates is 'x', surface tension for liquids is T and angle of contact is θ, then rise of liquid between the plates due to capillary will be

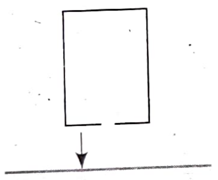
(a) $\frac{T\cos\theta}{xd}$ (b) $\frac{2T\cos\theta}{xdg}$

(c) $\frac{2T}{xdg\cos\theta}$ (d) $\frac{T\cos\theta}{xdg}$

11. Assuming the xylem tissues through which water rises from root to the branches in a tree to be of uniform cross-section find the maximum radius of xylem tube in a 10 m high coconut tree so that water can rise to the top. (surface tension of water = 0.1 N/m, Angle of contact of water with xylem tube = 60°)

(a) 1 cm (b) 1 mm (c) 10 μm (d) 1 μm

12. An empty container has a circular hole of radius r at its bottom. The container is pushed into water very slowly as shown. To what depth the lower surface of container (from surface of water) can be pushed into water such that water does not flow into the container?



(Surface tension of water = T, density of water = ρ)

(a) $\frac{2T}{\rho gr}$ (b) $\frac{4T}{\rho gr}$ (c) $\frac{T}{\rho gr}$ (d) $\frac{T}{2\rho gr}$

Multiple Correct Answers Type

13. Which of the following statements are not correct about a soap bubble?

(a) Work done in forming the bubble of radius R and surface tension T is $4\pi R^2T$

(b) Work done in doubling the radius of a bubble of radius R and surface tension T is $24\pi R^2T$

(c) Pressure inside a bubble is greater than inside a drop of the same radius and of the same liquid.

(d) Pressure inside a bubble is lesser than outside it.

14. If for a liquid in a vessel force of cohesion is twice of adhesion:

(a) the meniscus will be convex.

(b) the liquid will wet the solid.

(c) the angle of contact will be obtuse.

(d) there will be capillary descent.

Fill in the Blanks Type

15. If the surface of a liquid is plane, then the angle of contact of the liquid with the walls of container is......

16. In a capillary tube, water rises by 1.2 mm. The height of water that will rise in another capillary tube having half the radius of the first, is ....

17. A capillary tube of radius r is dipped in a liquid of density ρ and surface tension S. If the angle of contact is θ, the pressure difference between the two surfaces in the beaker and the capillary.........

18. Two soap bubbles of radii r_1 and r_2 equal to 4 cm and 5 cm are touching each other over a common surface S_1S_2 (shown in the figure in the solution). Its radius will be..........

19. A capillary tube of radius R is immersed in water and water rises in it to a height H. Mass of water in the capillary tube is M. If the radius of the tube is doubled, mass of water that will rise in the capillary tube will now be ....

20. Two capillary tubes of the same diameter are put vertically one each in two liquids whose relative densities are 0.8 and 0.6 and surface tensions are 60 and 50 dyne/cm respectively. Ratio of heights of liquids in the two tubes $\frac{h_1}{h_2}$ is

21. If the excess pressure inside a soap bubble is balanced by oil column of height 2 mm, then the surface tension of soap solution will be (r = 1 cm and density d = 0.8 gm/cc)

Answers Key

Single Correct Answer Type

1. (a) **2.** (c) **3.** (c) **4.** (b) **5.** (c)
6. (c) **7.** (b) **8.** (b) **9.** (b) **10.** (b)
11. (d) **12.** (a)

Multiple Correct Answers Type

13. (a, d) **14.** (a, c, d)

Fill in the Blanks Type

15. 0° **16.** 2.4 mm **17.** $\frac{2S}{r}\cos\theta$
18. 20 cm **19.** $2M$ **20.** $\frac{9}{10}$
21. 3.9×10^{-2} N/m

DPP 5.5

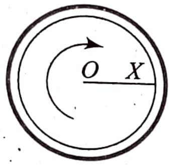
Viscosity

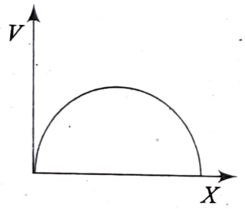
Single Correct Answer Type

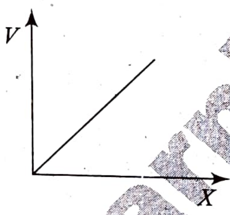
1. Consider the following statements:
   (i) Young's modulus is numerically equal to the stress which will double the length of a wire
   (ii) Viscosity of gases is greater than that of liquids
   (iii) The surface tension of a liquid decreases due to the presence of insoluble contamination

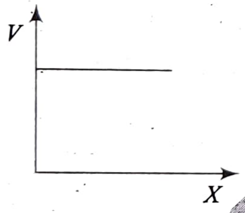
   The number of above statements that are true is
   (a) one (b) two (c) three (d) zero

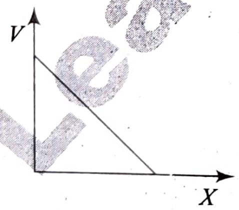
2. The diagram shows a cup of tea seen from above. The tea has been stirred and is now rotating without turbulence. A graph showing the speed v with which the liquid is crossing points at a distance X from O along a radius XO would look like



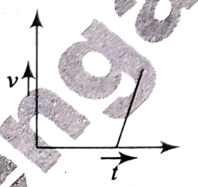
(a)


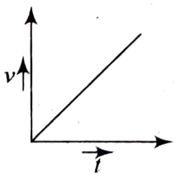
(b)


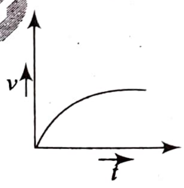
(c)


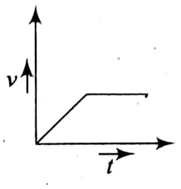
(d)


3. A tall cylinder is filled with viscous oil. A round pebble is dropped from the top with zero initial velocity. From the plot shown in the figure, indicate the one that represents the velocity (v) of the pebble as a function of time (t).

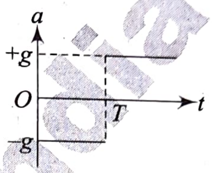
(a)


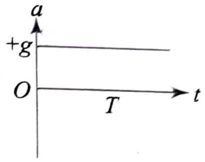
(b)


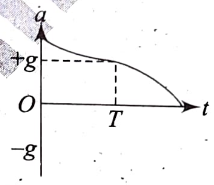
(c)


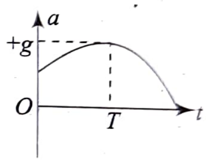
(d)


4. A ball is thrown vertically upwards at time $t = 0$. Air resistance is not negligible and the acceleration of free fall is g. The ball reaches a maximum height at time $t = T$ and the descends, reaching terminal speed. Which graph best shows the variation with time t of the acceleration a of the ball?

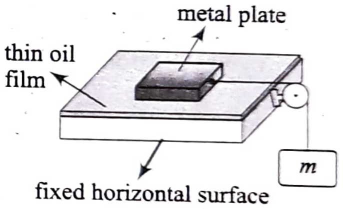
(a)


(b)


(c)


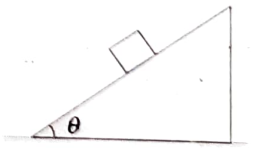
(d)


5. A rectangular metal plate has dimensions of 10 cm × 20 cm. A thin film of oil separates the plate from a fixed horizontal surface. The separation between the rectangular plate and the horizontal surface is 0.2 mm. An ideal string is attached to the plate and passes over an ideal pulley to a mass m. When $m = 125$ gm, the metal plate moves at constant speed of 5 cm/s across the horizontal surface. Then the coefficient of viscosity of oil in dyne-s/cm^2 is (Use $g = 1000$ cm/s^2)



   (a) 5 (b) 25 (c) 2.5 (d) 50

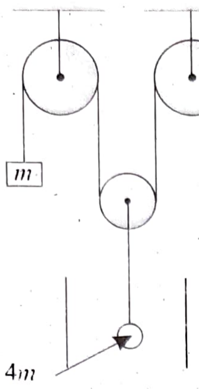
6. A cubical block of side 'a' and density 'ρ' slides over a fixed inclined plane with constant velocity 'v'. There is a thin film of viscous fluid of thickness 't' between the plane and the block. Then the coefficient of viscosity of the thin film will be: (Acceleration due to gravity is g)



   (a) $\eta = \dfrac{\rho a g t \sin\theta}{v}$ (b) $\dfrac{\rho a g t^2 \sin\theta}{v}$

   (c) $\dfrac{v}{\rho a g t \sin\theta}$ (d) none of these

7. A spherical ball of mass $4m$, density σ and radius r is attached to a pulley-mass system as shown in the figure. The ball is released in a liquid of coefficient of viscosity η and density $\rho\left(<\frac{\sigma}{2}\right)$. If the length of the liquid column is sufficiently long, the terminal velocity attained by the ball is given by (assume all pulleys to be massless and string as massless and inextensible):



(a) $\frac{2}{9}\frac{r^2(2\sigma-\rho)g}{\eta}$ (b) $\frac{2}{9}\frac{r^2(\sigma-2\rho)g}{\eta}$

(c) $\frac{2}{9}\frac{r^2(\sigma-4\rho)g}{\eta}$ (d) $\frac{2}{9}\frac{r^2(\sigma-3\rho)g}{\eta}$

8. When a ball is released from rest in a very long column of viscous liquid, its downward acceleration is 'a' (just after release). Then its acceleration when it has acquired two-third of the maximum velocity:

(a) $\frac{a}{3}$ (b) $\frac{2a}{3}$ (c) $\frac{a}{6}$ (d) none of these

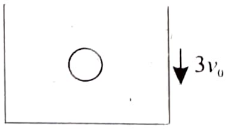
9. A sphere of mass m and radius r is projected in a gravity free space with speed v. If coefficient of viscosity of the medium in which it moves is $\frac{1}{6\pi}$, the distance travelled by the body before it stops is:

(a) $\frac{mv}{2r}$ (b) $\frac{2mv}{r}$ (c) $\frac{mv}{r}$ (d) $\frac{mv}{4r}$

10. A uniform solid sphere of relative density 5 is released in water filled in a long vertical tube. Its terminal velocity achieved is V. If another uniform solid sphere of the same material but double the radius is released in the same water, then the terminal velocity achieved will be

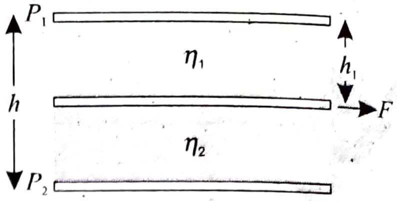
(a) V (b) $4V$ (c) $V/4$ (d) $2V$

11. A container filled with viscous liquid is moving vertically downwards with constant speed $3v_0$. At the instant shown, a sphere of radius r is moving vertically downwards (in liquid) has speed v_0. The coefficient of viscosity is η. There is no relative motion between the liquid and the container. Then at the shown instant, the magnitude of viscous force acting on sphere is



(a) $6\pi\eta rv_0$ (b) $12\pi\eta rv_0$ (c) $18\pi\eta rv_0$ (d) $24\pi\eta rv_0$

12. A thin horizontal movable plate is separated from two fixed horizontal plates P_1 and P_2 by two highly viscous liquids of coefficient of viscosity η_1 and η_2 as shown, where $\eta_2 = 4\eta_1$. Area of contact of movable plate with each fluid is the same. If the distance between two fixed plates is h, then the distance h_1 of movable plate from upper fixed plate such that the movable plate can be moved with a constant velocity by applying a minimum constant horizontal force F on movable plate is (assume velocity gradient to be uniform in each liquid).



(a) $\frac{h}{4}$ (b) $\frac{h}{2}$ (c) $\frac{2h}{3}$ (d) $\frac{h}{3}$

13. Two uniform solid balls of the same density and of radii r and $2r$ are dropped in air and fall vertically downwards. The terminal velocity of the ball with radius r is 1 cm s^{-1}, then the terminal velocity of the ball of radius $2r$ will be (neglect buoyant force on the balls.)

(a) 0.5 cm s^{-1} (b) 4 cm s^{-1}

(c) 1 cm s^{-1} (d) 2 cm s^{-1}

14. A sphere of radius R and density ρ_1 is dropped in a liquid of density σ. Its terminal velocity is v_1. If another sphere of radius R and density ρ_2 is dropped in the same liquid, its terminal velocity will be:

(a) $\left(\frac{\rho_2-\sigma}{\rho_1-\sigma}\right)v_1$ (b) $\left(\frac{\rho_1-\sigma}{\rho_2-\sigma}\right)v_1$

(c) $\left(\frac{\rho_1}{\rho_2}\right)v_1$ (d) $\left(\frac{\rho_2}{\rho_1}\right)v_1$

Multiple Correct Answers Type

15. Streamline flow is more likely for liquids with

(a) high density (b) high viscosity

(c) low density (d) low viscosity

16. A solid sphere moves at a terminal velocity of 20 m/s in air at a place where $g = 9.8$ m/s^2. The sphere is taken in a gravity free hall having air at the same pressure and pushed down at a speed of 20 m/s.

(a) its initial acceleration will be 9.8 m/s^2 downward

(b) its initial acceleration will be 9.8 m/s^2 upward

(c) the magnitude of acceleration will decrease as the time passes

(d) it will eventually stop

Answers Key

Single Correct Answer Type

1. (b) 2. (d) 3. (c) 4. (c) 5. (c)
6. (a) 7. (b) 8. (a) 9. (c) 10. (b)
11. (b) 12. (d) 13. (b) 14. (a)

Multiple Correct Answers Type

15. (b, c) 16. (b, c, d)

CHAPTER

6

Gravitation

DPP 6.1

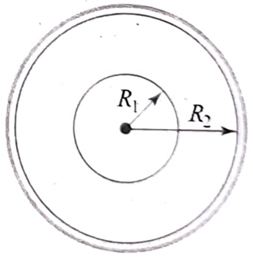
Kepler's Laws of Planetary Motion and Newton's Law of Gravitation

Subjective Type

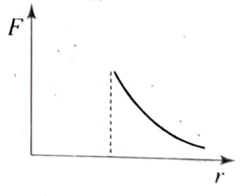
1. Two identical heavy spheres are separated by a distance 10 times their radius. Will an object placed at the mid-point of the line joining their centres be in stable equilibrium or unstable equilibrium? Give reason for your answer.
2. Is it possible for a body to have inertia but no weight?

Single Correct Answer Type

3. As observed from the earth, the sun appears to move in an approximate circular orbit. For the motion of another planet like mercury as observed from the earth, this would
   (a) be similarly true
   (b) not be true because the force between the earth and mercury is not inverse square law
   (c) not be true because the major gravitational force on mercury is due to the sun
   (d) not be true because mercury is influenced by forces other than gravitational forces
4. A sphere of mass M and radius R_2 has a concentric cavity of radius R_1 as shown in the figure. The force F exerted by the sphere on a particle of mass m located at a distance r from the centre of sphere varies as $(0 \le r \le \infty)$



(a)



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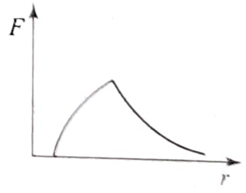

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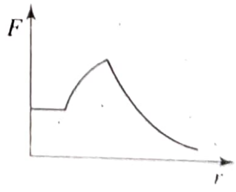

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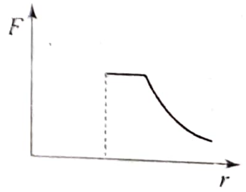
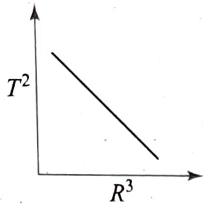
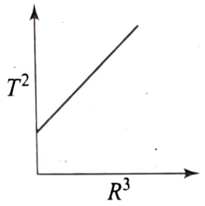


5. Which of the following graphs represents the motion of a planet moving about the sun?

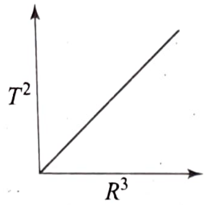
(a)



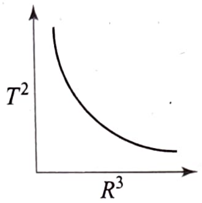
(b)



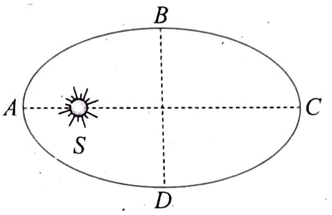
(c)



(d)



6. A planet is revolving around the sun as shown in elliptical path



The correct option is

(a) The time taken in travelling DAB is less than that for BCD
(b) The time taken in travelling DAB is greater than that for BCD
(c) The time taken in travelling CDA is less than that for ABC
(d) The time taken in travelling CDA is greater than that for ABC

7. In the previous question the orbital velocity of the planet will be minimum at

(a) A (b) B (c) C (d) D

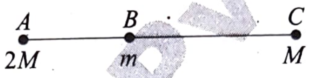
8. Different points in the earth are at slightly different distances from the sun and hence experience different forces due to gravitation. For a rigid body, we know that if various forces act at various points in it, the resultant motion is as if a net force acts on the CM (centre of mass) causing translation and a net torque at the CM causing rotation around an axis through the CM. For the earth-sun system (approximating the earth as a uniform density sphere).

(a) the torque is zero
(b) the torque causes the earth to spin
(c) the rigid body result is not applicable since the earth is not even approximately a rigid body
(d) the torque causes the earth to move around the sun

9. In our solar system, the inter-planetary region has chunks of matter (much smaller in size compared to planets) called asteroids. They

(a) will not move around the sun, since they have very small masses compared to the sun
(b) will move in an irregular way because of their small masses and will drift away into outer space
(c) will move around the sun in closed orbits but not obey Kepler's laws
(d) will move in orbits like planets and obey Kepler's laws

10. Particles of masses $2M$, m and M are respectively at points A, B and C with $AB = \frac{1}{2}(BC)$. m is much-much smaller than M and at time $t = 0$, they are all at rest as given in figure.
At subsequent times before any collision takes place.



(a) m will remain at rest
(b) m will move towards M
(c) m will move towards $2M$
(d) m will have oscillatory motion

Multiple Correct Answers Type

11. If the law of gravitation, instead of being inverse square law, becomes an inverse cube law

(a) planets will not have elliptic orbits
(b) circular orbits of planets is not possible
(c) projectile motion of a stone thrown by hand on the surface of the earth will be approximately parabolic
(d) there will be no gravitational force inside a spherical shell of uniform density

12. If the mass of the sun were ten times smaller and gravitational constant G were ten times larger in magnitude, then,

(a) walking on ground would become more difficult
(b) the acceleration due to gravity on the earth will not change
(c) raindrops will fall much faster
(d) airplanes will have to travel much faster

13. There have been suggestions that the value of the gravitational constant G becomes smaller when considered over very large time period (in billions of years) in the future. If that happens, for our earth,

(a) nothing will change
(b) we will become hotter after billions of years
(c) we will be going around but not strictly in closed orbits
(d) after sufficiently long time we will leave the solar system

14. Supposing Newton's law of gravitation for gravitation forces F_1 and F_2 between two masses m_1 and m_2 at positions r_1 and r_2 read

$$F_1 = -F_2 = -\frac{r_{12}}{r_{12}^3} G M_0^2 \left(\frac{m_1 m_2}{M_0^2}\right)^n$$

where M_0 is a constant of dimension of mass, $r_{12} = r_1 - r_2$ and n is a number. In such a case,

(a) the acceleration due to gravity on the earth will be different for different objects

(b) none of the three laws of Kepler will be valid
(c) only the third law will become invalid
(d) for *n* negative, an object lighter than water will sink in water

Fill in the Blanks Type

15. The mean radius of the earth's orbit around the sun is 1.5×10^{11}. The mean radius of the orbit of mercury around the sun is 6×10^{10} m. The mercury will rotate around the sun in nearly...........

16. Imagine a light planet revolving around a very massive star in a circular orbit of radius R with a period of revolution T. If the gravitational force of attraction between planet and star is proportional to $R^{-\frac{5}{2}}$, then T^2 is proportional to............

17. A planet moves around the sun. At a given point P, it is closest from the sun at a distance d_1 and has a speed v_1. At another point Q, when it is farthest from the sun at a distance d_2, its speed will be ....

18. Two planets revolve around the sun with frequencies N_1 and N_2 revolutions per year. If their average orbital radii be R_1 and R_2 respectively, then R_1/R_2 is equal to................

Answers Key

Single Correct Answer Type

3. (c) **4.** (b) **5.** (c) **6.** (a) **7.** (c)
8. (a) **9.** (d) **10.** (c)

Multiple Correct Answers Type

11. (a, c) **12.** (a, c, d) **13.** (c, d) 14. (a, c, d)

Fill in the Blanks Type

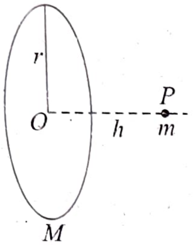
15. $\frac{1}{4}$ year **16.** $R^{7/2}$ **17.** $\frac{d_1 v_1}{d_2}$ **18.** $(N_2/N_1)^{2/3}$

DPP 6.2

Gravitation Field and Acceleration Due to Gravity

Subjective Type

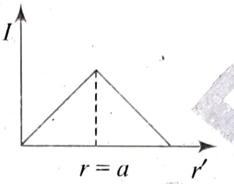
1. A mass m is placed at P a distance h along the normal through the centre O of a thin circular ring of mass M and radius r (see figure).

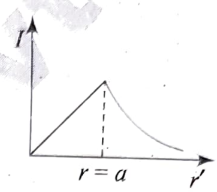


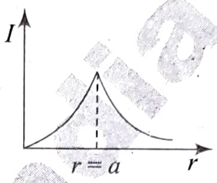
If the mass is moved further away such that OP becomes $2h$, by what factor the force of gravitation will decrease, if $h = r$?

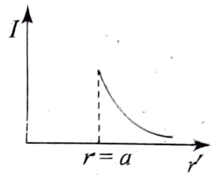
Single Correct Answer Type

2. At the surface of a certain planet, acceleration due to gravity is one-quarter of that on earth. If a brass ball is transported to this planet, then which one of the following statements is not correct?
   (a) The mass of the brass ball on this planet is a quarter of its mass as measured on earth
   (b) The weight of the brass ball on this planet is a quarter of the weight as measured on earth
   (c) The brass ball has the same mass on the other planet as on earth
   (d) The brass ball has the same volume on the other planet as on earth
3. The earth is an approximate sphere. If the interior contained matter which is not of the same density everywhere, then on the surface of the earth, the acceleration due to gravity
   (a) will be directed towards the centre but not the same everywhere
   (b) will have the same value everywhere but not directed towards the centre
   (c) will be the same everywhere in magnitude directed towards the centre
   (d) cannot be zero at any point
4. Which one of the following graphs represents correctly the variation of the gravitational field (F) with the distance (r) from the centre of a spherical shell of mass M and radius a

(a)


(b)


(c)


(d)


5. If the change in the value of 'g' at a height h above the surface of the earth is the same as at a depth x below it, then (both x and h being much smaller than the radius of the earth)
   (a) $x = h$ (b) $x = 2h$
   (c) $x = \frac{h}{2}$ (d) $x = h^2$
6. A body weighs 700 gm wt on the surface of the earth. How much will it weigh on the surface of a planet whose mass is $\frac{1}{7}$ and radius is half that of the earth?
   (a) 200 gm wt (b) 400 gm wt
   (c) 50 gm wt (d) 300 gm wt
7. Weight of a body of mass m decreases by 1% when it is raised to height h above the earth's surface. If the body is taken to a depth h in a mine, change in its weight is
   (a) 2% decrease (b) 0.5% decrease
   (c) 1% increase (d) 0.5% increase
8. Let g be the acceleration due to gravity at earth's surface and K be the rotational kinetic energy of the earth. Suppose the earth's radius decreases by 2% keeping all other quantities same, then
   (a) g decreases by 2% and K decreases by 4%
   (b) g decreases by 4% and K increases by 2%
   (c) g increases by 4% and K increases by 4%
   (d) g decreases by 4% and K increases by 4%
9. At what depth below the surface of the earth, acceleration due to gravity g will be half its value 1600 km above the surface of the earth
   (a) 4.2×10^6 m (b) 3.19×10^6 m
   (c) 1.59×10^6 m (d) None of these
10. Consider earth to be a homogeneous sphere. Scientist A goes deep down in a mine and scientist B goes high up in a balloon. The value of g measured by

(a) A goes on decreasing and that by B goes on increasing
(b) B goes on decreasing and that by A goes on increasing
(c) Each decreases at the same rate
(d) Each decreases at different rates

11. The mass of the moon is $\frac{1}{81}$ of the earth but the gravitational pull is $\frac{1}{6}$ of the earth. It is due to the fact that

(a) The radius of the moon is $\frac{81}{6}$ of the earth
(b) The radius of the earth is $\frac{9}{\sqrt{6}}$ of the moon
(c) Moon is the satellite of the earth
(d) None of the above

12. If a planet consists of a satellite whose mass and radius were both half that of the earth, the acceleration due to gravity at its surface would be (g on earth = 9.8 m/sec^2)

(a) 4.9 m/sec^2 (b) 8.9 m/sec^2
(c) 19.6 m/sec^2 (d) 29.4 m/sec^2

13. A cavity of radius $R/2$ is made inside a solid sphere of radius R. The centre of the cavity is located at a distance $R/2$ from the centre of the sphere. The gravitational force on a particle of mass 'm' at a distance $R/2$ from the centre of the sphere on the line joining both the centres of sphere and cavity is (opposite to the centre of cavity). [Here $g = GM/R^2$, where M is the mass of the solid sphere]

(a) $\frac{mg}{2}$ (b) $\frac{3mg}{8}$
(c) $\frac{mg}{16}$ (d) none of these

14. A small area is removed from a uniform spherical shell of mass M and radius R. Then the gravitational field intensity near the hollow portion is

(a) $\frac{GM}{R^2}$ (b) $\frac{GM}{2R^2}$ (c) $\frac{3GM}{2R^2}$ (d) Zero

Fill in the Blanks Type

15. If R is the radius of the earth and g the acceleration due to gravity on the earth's surface, the mean density of the earth is.........................

16. The depth d at which the value of acceleration due to gravity becomes $\frac{1}{n}$ times the value at the surface is [R = radius of the earth]

17. At what altitude in metre will the acceleration due to gravity be 25% of that at the earth's surface (Radius of earth = R metre)

18. If the radius of the earth shrinks by 1.5% (mass remaining the same), then the value of acceleration due to gravity changes by..................

19. What should be the angular speed of earth, so that body lying on equator may appear weightlessness.........
(g = 10 m/s^2, R = 6400 km)

20. If both the mass and the radius of the earth decrease by 1%, the value of the acceleration due to gravity will ......

Answers Key

Subjective Type

1. $F' = \frac{4\sqrt{2}}{5\sqrt{5}}F$

Single Correct Answer Type

2. (a) 3. (d) 4. (d) 5. (b) 6. (b)
7. (b) 8. (c) 9. (a) 10. (d) 11. (b)
12. (c) 13. (b) 14. (b)

Fill in the Blanks Type

15. $3g/4\pi RG$ 16 $R\left(\frac{n-1}{n}\right)$ 17. R
18. 3% 19. $\frac{1}{800}$ rad/s 20. Increase by 1%

DPP 6.3

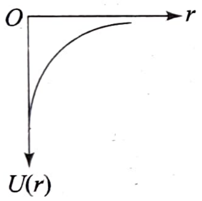
Gravitation Potential, Energy and Escape Velocity

Subjective Type

1. An object of mass m is raised from the surface of the earth to a height equal to the radius of the earth, that is, taken from a distance R to $2R$ from the centre of the earth. What is the gain in its potential energy?
2. A star like the sun has several bodies moving around it at different distances. Consider that all of them are moving in circular orbits. Let r be the distance of the body from the centre of the star and let its linear velocity be v, angular velocity ω, kinetic energy K, gravitational potential energy U, total energy E and angular momentum l. As the radius r of the orbit increases, determine which of the above quantities increase and which ones decrease.

Single Correct Answer Type

3. A shell of mass M and radius R has a point mass m placed at a distance r from its centre. The gravitational potential energy $U(r)$ vs. r will be

(a)


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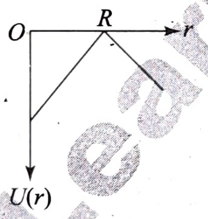

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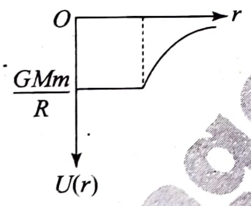

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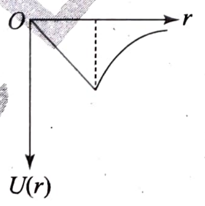


4. A missile is launched with a velocity less than the escape velocity. The sum of its kinetic and potential energy is
   - (a) positive
   - (b) negative
   - (c) zero
   - (d) may be positive or negative depending upon its initial velocity
5. The gravitational potential energy of a body of mass 'm' at the earth's surface $-mgR_e$. Its gravitational potential energy at a height R_e from the earth's surface will be (Here R_e is the radius of the earth)

   (a) $-2mgR_e$ (b) $2mgR_e$

   (c) $\frac{1}{2}mgR_e$ (d) $-\frac{1}{2}mgR_e$
6. A rocket of mass M is launched vertically from the surface of the earth with an initial speed V. Assuming the radius of the earth to be R and negligible air resistance, the maximum height attained by the rocket above the surface of the earth is

   (a) $R/\left(\frac{gR}{2V^2}-1\right)$ (b) $R\left(\frac{gR}{2V^2}-1\right)$

   (c) $R/\left(\frac{2gR}{V^2}-1\right)$ (d) $R\left(\frac{2gR}{V^2}-1\right)$
7. Two bodies of masses m_1 and m_2 are initially at rest at infinite distance apart. They are then allowed to move towards each other under mutual gravitational attraction. Their relative velocity of approach at a separation distance r between them is

   (a) $\left[2G\frac{(m_1-m_2)}{r}\right]^{1/2}$ (b) $\left[\frac{2G}{r}(m_1+m_2)\right]^{1/2}$

   (c) $\left[\frac{r}{2G(m_1m_2)}\right]^{1/2}$ (d) $\left[\frac{2G}{r}m_1m_2\right]^{1/2}$
8. A body of mass m kg starts falling from a point $2R$ above the Earth's surface. Its kinetic energy when it has fallen to a point 'R' above the Earth's surface [R—Radius of Earth, M—Mass of Earth, G—Gravitational Constant]

   (a) $\frac{1}{2}\frac{GMm}{R}$ (b) $\frac{1}{6}\frac{GMm}{R}$

   (c) $\frac{2}{3}\frac{GMm}{R}$ (d) $\frac{1}{3}\frac{GMm}{R}$
9. Maximum height reached by a rocket fired with a speed equal to 50% of the escape velocity from earth's surface is:

   (a) $R/2$ (b) $16R/9$ (c) $R/3$ (d) $R/8$
10. Three identical stars, each of mass M, form an equilateral triangle (stars are positioned at the corners) that rotates around the centre of the triangle. The system is isolated and edge length of the triangle is L. The amount of work done, that is required to dismantle the system, is:

    (a) $\frac{3GM^2}{L}$ (b) $\frac{3}{2}\frac{GM^2}{L}$

(c) $\frac{3}{4}\frac{GM^2}{L}$ (d) $\frac{GM^2}{2L}$

Multiple Correct Answers Type

11. The radius and mass of earth are increased by 0.5%. Which of the following statements are true at the surface of the earth?

(a) g will increase
(b) g will decrease
(c) Escape velocity will remain unchanged
(d) Potential energy will remain unchanged

Fill in the Blanks Type

12. Four particles each of mass M are located at the vertices of a square with side L. The gravitational potential due to this at the centre of the square is.............

13. The gravitational field due to a mass distribution is $E = K/x^2$ in the x-direction. (K is a constant). Taking the gravitational potential to be zero at infinity, its value at a distance x is

14. A body of mass m rises to height $h = R/5$ from the earth's surface, where R is earth's radius. If g is acceleration due to gravity at earth's surface, the increase in potential energy is.................

15. Escape velocity of a body of 1 kg mass on a planet is 100 m/sec. Gravitational potential energy of the body at the planet is ....

16. For the moon to cease to remain the earth's satellite, its orbital velocity has to increase by a factor of ....

17. The ratio of the radii of planets A and B is k_1 and ratio of acceleration due to gravity on them is k_2. The ratio of escape velocities from them will be ....

18. If mass of earth is M, radius is R and gravitational constant is G, then work done to take 1 kg mass from earth surface to infinity will be.........

Answers Key

Subjective Type

1. $\frac{1}{2}mgr$

Single Correct Answer Type

3. (c) **4.** (b) **5.** (d) **6.** (c) **7.** (b)
8. (b) **9.** (c) **10.** (b)

Multiple Correct Answers Type

11. (b, c, d)

Fill in the Blanks Type

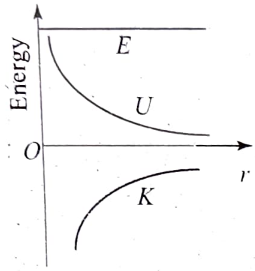
12. $-\sqrt{32}\frac{GM}{L}$ **13.** $K/2x^2$ **14.** $\frac{5}{6}mgh$
15. –5000 J **16.** $\sqrt{2}$ **17.** $\sqrt{k_1k_2}$
18. $\frac{GM}{R}$

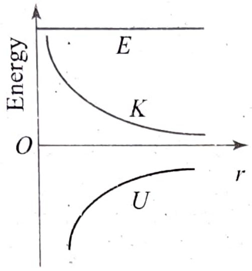
DPP 6.4

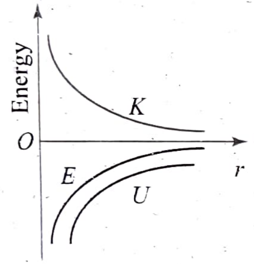
Motion of Satellite

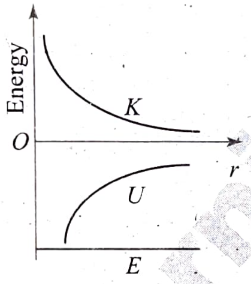
Single Correct Answer Type

1. The correct graph representing the variation of total energy (E_t) kinetic energy (E_k) and potential energy (U) of a satellite with its distance from the centre of earth is

(a) 

(b) 

(c) 

(d) 

2. A satellite is seen after every 6 hours over the equator. It is known that it rotates opposite to that of earth's direction. Then the angular velocity (in radians per hour) of the satellite about the centre of earth will be:

(a) $\frac{\pi}{2}$ (b) $\frac{\pi}{3}$ (c) $\frac{\pi}{4}$ (d) $\frac{\pi}{8}$

3. A satellite is seen after each 8 hours over equator at a place on the earth when its sense of rotation is opposite to the earth. The time interval after which it can be seen at the same place when the sense of rotation of earth and satellite is same will be:

(a) 8 hours (b) 12 hours
(c) 24 hours (d) 6 hours

4. Two satellites of masses m_1 and $m_2 (m_1 > m_2)$ are revolving round the earth in circular orbits of radius r_1 and $r_2 (r_1 > r_2)$ respectively. Which of the following statements is true regarding their speeds v_1 and v_2?

(a) $v_1 = v_2$ (b) $v_1 < v_2$ (c) $v_1 > v_2$ (d) $\frac{v_1}{r_1} = \frac{v_2}{r_2}$

5. The ratio of the K.E. required to be given to the satellite to escape earth's gravitational field to the K.E. required to be given so that the satellite moves in a circular orbit just above earth atmosphere is

(a) One (b) Two (c) Half (d) Infinity

6. A satellite is moved from one circular orbit around the earth to another of lesser radius. Which of the following statement is true?

(a) The kinetic energy of satellite increases and the gravitational potential energy of satellite-earth system increases.
(b) The kinetic energy of satellite increases and the gravitational potential energy of satellite-earth system decreases.
(c) The kinetic energy of satellite decreases and the gravitational potential energy of satellite-earth system decreases.
(d) The kinetic energy of satellite decreases and the gravitational potential energy of satellite-earth system increases.

7. The orbital velocity of an artificial satellite in a circular orbit just above the earth's surface is v. For a satellite orbiting at an altitude of half of the earth's radius, the orbital velocity is

(a) $\frac{3}{2}v$ (b) $\sqrt{\frac{3}{2}}v$ (c) $\sqrt{\frac{2}{3}}v$ (d) $\frac{2}{3}v$

8. A satellite is moving around the earth with speed v in a circular orbit of radius r. If the orbit radius is decreased by 1%, its speed will

(a) Increase by 1% (b) Increase by 0.5%
(c) Decrease by 1% (d) Decrease by 0.5%

9. A satellite revolves in elliptical orbit around a planet of mass M. Its time period is T and M is at the centre of the path. The length of the major axis of the path is: (neglect the gravitational effect of other objects in space)

(a) $2\left[\frac{GMT^2}{4\pi^2}\right]^{1/3}$ (b) $\left[\frac{GMT^2}{4\pi^2}\right]^{1/3}$

(c) $\frac{1}{2}\left[\frac{GMT^2}{4\pi^2}\right]^{1/3}$ (d) none of these

10. Two identical satellites are at R and $7R$ away from earth surface, the wrong statement is (R = Radius of earth)

(a) Ratio of total energy will be 4
(b) Ratio of kinetic energies will be 4
(c) Ratio of potential energies will be 4
(d) Ratio of total energy will be 4 but ratio of potential and kinetic energies will be 2

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11. In the following four periods
    (i) Time of revolution of a satellite just above the earth's surface (T_{st})
    (ii) Period of oscillation of mass inside the tunnel bored along the diameter of the earth (T_{ma})
    (iii) Period of simple pendulum having a length equal to the earth's radius in a uniform field of 9.8 N/kg (T_{sp})
    (iv) Period of an infinite length simple pendulum in the earth's real gravitational field (T_{is})
    (a) $T_{st} > T_{ma}$ (b) $T_{ma} > T_{st}$
    (c) $T_{sp} < T_{is}$ (d) $T_{st} = T_{ma} = T_{sp} = T_{is}$

12. A satellite with kinetic energy E_k is revolving around the earth in a circular orbit. How much more kinetic energy should be given to it so that it may just escape into outer space?
    (a) E_k (b) $2E_k$ (c) $\frac{1}{2}E_k$ (d) $3E_k$

Multiple Correct Answers Type

13. Which of the following are true?
    (a) A polar satellite goes around the earth's pole in north-south direction
    (b) A geostationary satellite goes around the earth in east-west direction
    (c) A geostationary satellite goes around the earth in west-east direction
    (d) A polar satellite goes around the earth in east-west direction

14. Two artificial satellites of the same mass are moving around the earth in circular orbits of different radii. In comparison to the satellite with lesser orbital radius, the other satellite with higher orbital radius will have:
    (a) greater kinetic energy
    (b) greater potential energy
    (c) greater total energy
    (d) greater magnitude of angular momentum, about the centre of the circular orbit

Fill in the Blanks Type

15. A satellite which is geostationary in a particular orbit is taken to another orbit. Its distance from the centre of earth in new orbit is 2 times that of the earlier orbit. The time period in the second orbit is.............

16. Two satellites A and B go round a planet P in circular orbits having radii $4R$ and R respectively. If the speed of the satellite A is $3V$, the speed of the satellite B will be.....

17. Orbital velocity of earth's satellite near the surface is 7 km/s. When the radius of the orbit is 4 times than that of earth's radius, then orbital velocity in that orbit is ....

18. The orbital speed of an artificial satellite very close to the surface of the earth is V_e. Then the orbital speed of another artificial satellite at a height equal to three times the radius of the earth is ....

19. A satellite moves round the earth in a circular orbit of radius R making one revolution per day. A second satellite moving in a circular orbit, moves round the earth once in 8 days. The radius of the orbit of the second satellite is ....

20. The mean radius of the earth is R, its angular speed on its own axis is ω and the acceleration due to gravity at earth's surface is g. The cube of the radius of the orbit of a geostationary satellite will be............

21. Given radius of Earth 'R' and length of a day 'T' the height of a geostationary satellite is [G—Gravitational Constant, M—Mass of Earth]

Answers Key

Single Correct Answer Type

1. (c) 2. (c) 3. (c) 4. (b) 5. (b)
6. (b) 7. (c) 8. (b) 9. (a) 10. (d)
11. (c) 12. (a)

Single Correct Answers Type

13. (a, c) 14. (b, c, d)

Fill in the Blanks Type

15. $48\sqrt{2}$ hours 16. 6 V 17. 3.5 km/s
18. $0.5V_o$ 19. $4R$ 20. R^2g/ω^2
21. $\left(\frac{GMT^2}{4\pi^2}\right)^{1/3} - R$